

WATER SOLUBLE PRODRUGS OF HINDERED ALCOHOLS

Background of the Invention

1. Field of the Invention

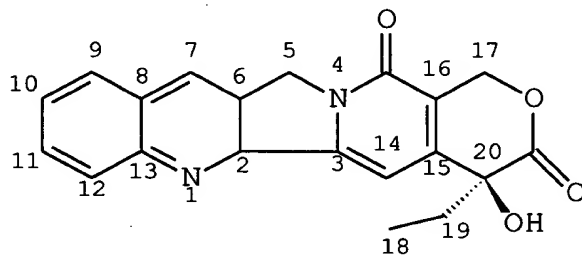
The present invention relates to novel water-soluble prodrugs of aliphatic or aromatic hindered hydroxyl group containing pharmaceuticals. Particularly, the present invention concerns novel water-soluble phosphonooxymethyl ethers of hindered alcohol and phenol containing pharmaceuticals, such as camptothecin, propofol, etoposide, Vitamin E and Cyclosporin A. The present invention also relates to intermediates used to create the final prodrugs as well as pharmaceutical compositions containing the novel compounds.

2. Background Art

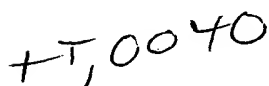
The successful delivery of a pharmaceutical to a patient is of critical importance in the treatment of disorders. However, the use of many clinical drugs with known properties is limited by their very low water solubility. As a result of low water solubility these drugs must be formulated in co-solvent pharmaceutical vehicles, including surfactants. These surfactants have

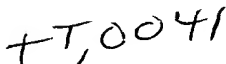
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formulation and physical changes to the formulation such as an increase in oil droplet size can lead to lung embolisms, etc. A water soluble and chemically stable prodrug of propofol would provide several advantages.

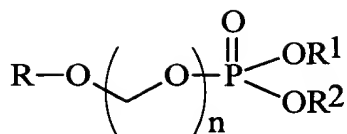
5 Such a formulation could be a simple aqueous solution that could be admixed with other drugs. If the prodrug itself was painless, the prodrug may be more patient friendly, and finally there should be no toxicity due to the vehicle. Other poorly water soluble, sterically
10 hindered phenols are the anticancer drug, etoposide and Vitamin E (alpha-tocopherol).

The present invention provides a water soluble form of alcohol and phenol containing drugs such as camptothecin and propofol. With respect to camptothecin,
15 compounds according to the present inventions are phosphonooxymethyl ethers of camptothecin in the form of the free acid and pharmaceutically acceptable salts thereof. The water solubility of the acid and the salts facilitates preparation of pharmaceutical formulations.
20 All of the prodrugs according to the present invention exhibit superior water solubility compared to their respective parent drugs. The methods developed for the compounds of the present invention can be useful for conversion of many other water insoluble medicinal agents
25 having aliphatic or aromatic hindered hydroxyl groups to the water soluble derivatives.

Summary of the Invention

The invention described herein involves new compositions of matter. The invention relates to the
30 water soluble phosphonooxymethyl derivatives of alcohol and phenol containing pharmaceuticals represented by the general formula I:

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I

The above formula I is the derivative of ROH, wherein ROH represents an alcohol- or phenol-containing drug, such as camptothecin, propofol, etoposide, vitamin

E and cyclosporin A. In the above formula I, n represents an integer of 1 or 2. When n is 2, ROH is preferably a phenol-containing pharmaceutical, such as propofol. Also included are some drugs for which injectable forms are not possible due to their inherent poor water solubility. These include danazol, methyltestosterone, iodoquinol and atovaquone. R¹ is hydrogen or an alkali metal ion including sodium, potassium or lithium or a protonated amine or protonated amino acid or any other pharmaceutically acceptable cation. R² is hydrogen or an alkali metal ion including sodium, potassium or lithium or a protonated amine or a protonated amino acid or any other pharmaceutically acceptable cation. After intravenous or oral administration, the derivatives according to formula I are converted back to the parent drugs by hydrolysis and/or phosphatase.

Accordingly, it is an object of the present invention to develop derivatives of water insoluble drugs which exhibit good activity and water solubility.

It is another object of the present invention to develop pharmaceutical compositions of these water soluble compounds, which comprises an amount of the compound of formula I and a pharmaceutically acceptable carrier.

It is another object of the present invention to develop drug derivatives having good stability at pH levels suitable for making pharmaceutical formulations,

but quickly break down in vivo under physiological conditions, to potentially act as prodrugs.

Brief Description of the Drawings

5 The drawings of the present application are explained as follows:

Figure 1 illustrates an *in vitro* enzymatic conversion of propofol prodrug to propofol.

10 Figure 2 illustrates the blood concentration change of propofol with respect to time from administration of the propofol prodrug or Diprivan® in a dog study.

Figure 3 illustrates an *in vitro* enzymatic conversion of camptothecin prodrug to camptothecin.

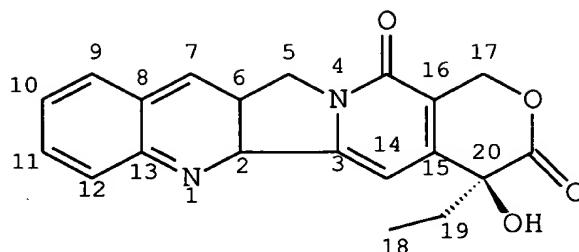
15 Figure 4 illustrates the correlation between plasma concentration of camptothecin from the camptothecin prodrug and from camptothecin in organic co-solvents for a rat study.

Detailed Description of the Invention

20 In the present specification, unless otherwise specified or in context, the following definitions apply.

25 "Phosphono-" means the group $-P(O)(OH)_2$ and "phosphonooxymethoxy" or "phosphonooxymethyl ether" means generically the group $-OCH_2OP(O)(OH)_2$. "Methylthiomethyl" refers to the group $-CH_2SCH_3$. The present invention also encompasses compounds wherein $n=2$ such that a "phosphono-di(oxymethyl) ether" generically means the group $-OCH_2OCH_2OP(O)(OH)_2$.

30 "Camptothecin moiety" denotes moiety containing the twenty carbon camptothecin core framework including two nitrogen atoms and four oxygen atoms as represented by the structural formula shown below with the absolute configuration.



The numbering system shown above is one used in conventional camptothecin derivatives, and is followed throughout the application. For example the notation C20 refers to the carbon atom labeled as "20".

5 "Camptothecin analogue" refers to a compound having the basic camptothecin core framework. It is to be understood that camptothecin analogues encompass compounds including but not limited to the following compounds: Topotecan, available from SmithKline Beecham, 10 Irinotecan (CPT-11), available from Pharmacia & Upjohn, 9-Aminocamptothecin (9AC), 9-Nitrocamptothecin (9NC), GI 147211C, available from Glaxo Wellcome, and DX-8951f (the previous six camptothecin analogues are currently under clinical investigation and are described in a review 15 conducted by the Pacific West Cancer Fund authored by Claire McDonald (December 1997).

Additionally, several other non-limiting Camptothecin analogues which are herein incorporated by reference are disclosed by Sawada et al., *Current 20 Pharmaceutical Design*, Vol. 1, No. 1, pp 113-132, as well as United States Patents Nos. 5,646,159, 5,559,235, 5,401,747, 5,364,858, 5,342,947, 5,244,903, 5,180,722, 5,122,606, 5,122,526, 5,106,742, 5,053,512, 5,049,668, 4,981,968 and 4,894,456.

25 Several pharmaceutical compounds including their respective derivatives of camptothecin contain more than one hydroxyl group, for example 10-hydroxycamptothecin, topotecan and several others listed in the above

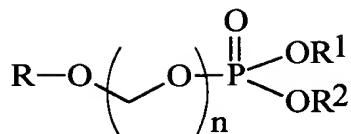
references. It is herein understood that the present invention may be applied to more than one hydroxyl group. This may be accomplished by protecting the additional hydroxyl group prior to derivatization.

5 "Phosphono protecting groups" means moieties, which can be employed to block or protect the phosphono functional group. Preferably, such protecting groups are those that can be removed by methods that do not appreciably affect the rest of the molecule. Suitable
10 phosphonooxy protecting groups include for example benzyl (denoted by "Bn"), t-butyl, and allyl groups.

"Pharmaceutically acceptable salt" means a metal or an amine salt of the acidic phosphono group in which the cation does not contribute significantly to the toxicity
15 or biological activity of the active compound. Suitable metal salts include lithium, potassium, sodium, calcium, barium, magnesium, zinc, and aluminum salts. Preferred salts are sodium and potassium salts. Suitable amine salts are for example, ammonia, tromethamine,
20 triethanolamine, ethylenediamine, glucamine, N-methylglucamine, glycine, lysine, ornithine, arginine, ethanolamine, to name but a few. Preferred amine salts are lysine, arginine, N-methylglucamine, and tromethamine salts.

25 In the specification and in the claims, the term $-OCH_2OP(O)(OH)_2$ is intended to encompass both the free acid and its pharmaceutically acceptable salts, unless the context indicates specifically that the free acid is intended.

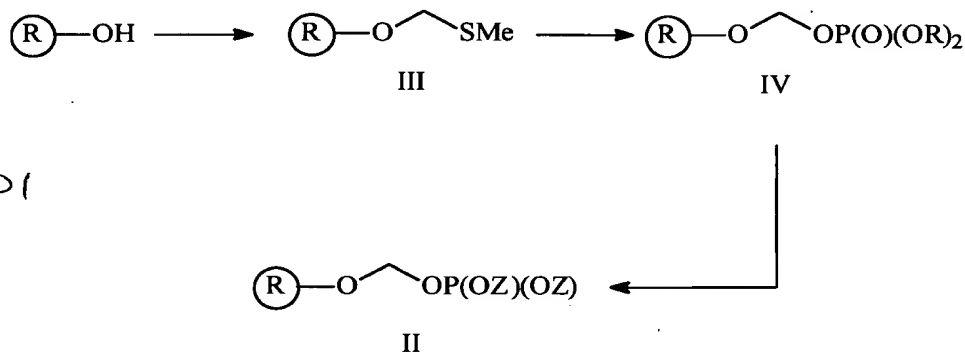
30 One aspect of the present invention provides for derivatives of alcohol and phenol containing pharmaceuticals as shown in formula I:



I

The derivatives according to formula I can be prepared according to the reaction sequence shown in Scheme 1:

Scheme 1



wherein ROH represents an alcohol- or phenol-containing drug, such as camptothecin, propofol, etoposide, vitamin E, cyclosporin A. It is to be understood that the above pathway is just one of several alternate pathways. These alternate pathways will become evident upon review of the following disclosure and examples.

An example of the above Scheme 1 can be illustrated using the compound camptothecin. It is to be understood that these schemes are applicable to other compounds encompassed by formula I of the present invention, such as those listed above. Accordingly, another aspect of the present invention provides camptothecin derivatives of according to formula II:

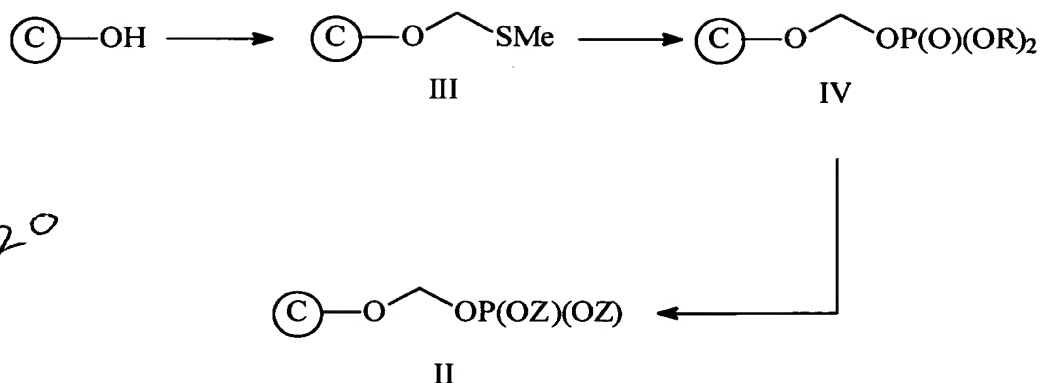
which include the free acid wherein Z is hydrogen and pharmaceutically acceptable salts thereof wherein Z is metal or amine. Alternatively, formula II includes diacids where Z is metal or amine in both occurrences.

The preferred pharmaceutically acceptable salts of a compound of formula II are alkali salts including lithium, sodium, and potassium salts; and amine salts including triethylamine, triethanolamine, ethanolamine, arginine, lysine and N-methylglucamine salts.

The most preferred embodiments of camptothecin derivatives of formula II include the following compounds: (20)-O-phosphonoxymethylcamptothecin, (20)-O-phosphonoxymethylcamptothecin mono- or di-sodium salt, (20)-O-phosphonoxymethylcamptothecin mono or dipotassium salt, (20)-O-phosphonoxymethylcamptothecin mono- or di-arginine salt, (20)-O-phosphonoxymethylcamptothecin mono- or di-lysine salt, (20)-O-phosphonoxymethylcamptothecin mono- or di-N-methylglucamine salt and (20)-O-phosphonoxymethylcamptothecin mono- or di-triethanolamine salt.

Compounds of formula II may be prepared directly from camptothecin (shown as ©-OH) according to the reaction sequence shown in Scheme 2:

Scheme 2



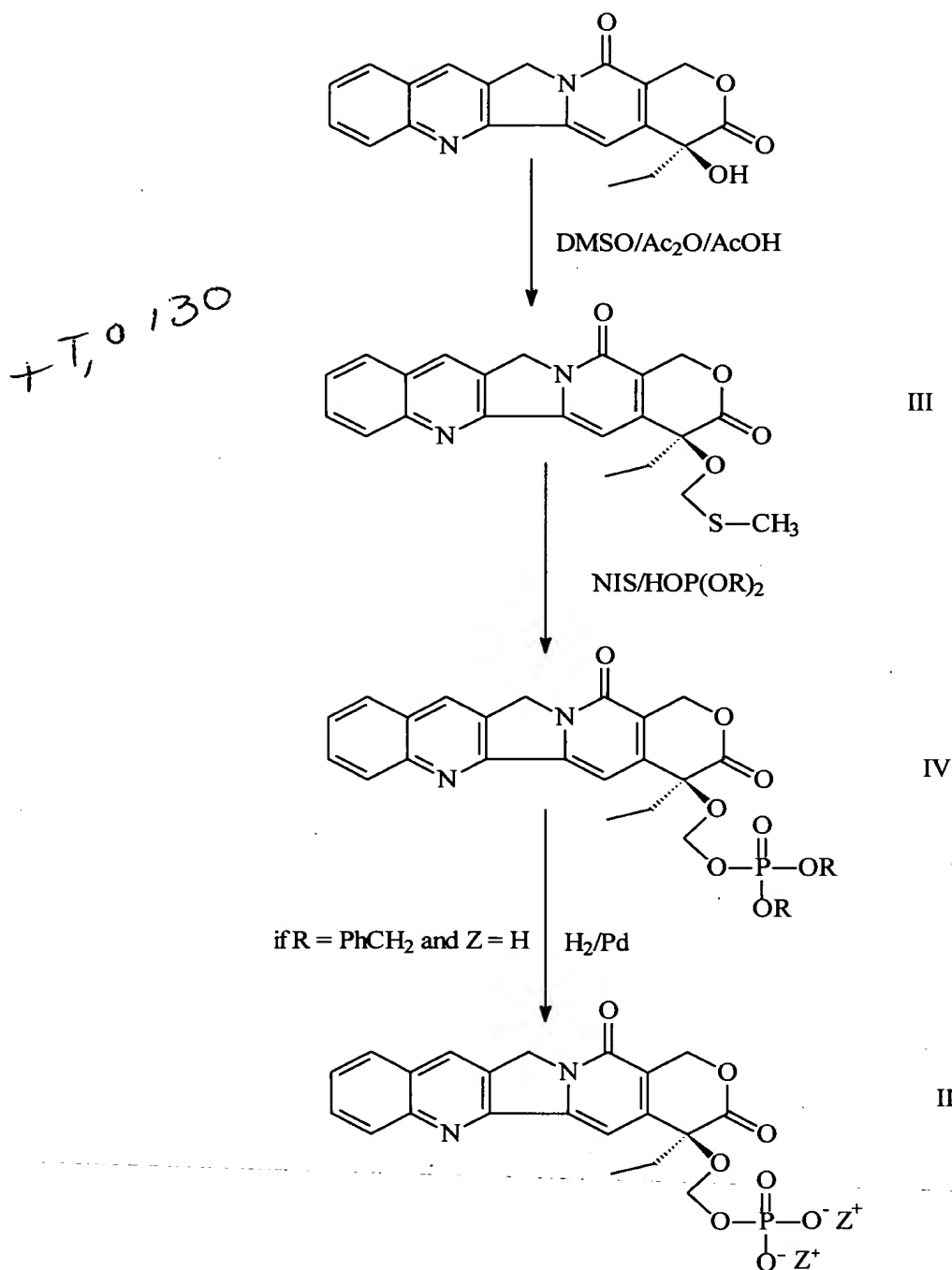
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A compound of formula III (methylthiomethyl ether, MTM ether) may be prepared by treating camptothecin with dimethylsulfoxide/acetic anhydride/acetic acid.

In the second step shown in Scheme 2, the methylthiomethyl ether is converted to the corresponding protected phosphonoxymethyl ether (compound of formula IV). This is accomplished by treating the MTM ether with N-iodosuccinamide and protected phosphate HOP(O)(OR)₂. In the third step, the phosphono protecting groups are removed to provide a compound of formula II. For example, a suitable phosphono protecting group(s) is benzyl that may be removed by catalytic hydrogenolysis.

The general process of Scheme 2 for the preparation of a compound of formula I is more particularly exemplified in Scheme 3:

Scheme 3



In the first step, the free hydroxy group of the camptothecin is converted to the corresponding methylthiomethyl ether (-OCH₂SCH₃) group. This conversion may be accomplished by reaction with dimethylsulfoxide in the presence of acetic anhydride and acetic acid. This

method, commonly known as the Pummer reaction was successfully applied by Bristol-Myers Squibb for methylthiomethylation of taxol (Europ.Pat.0604910A1, Bioorg.Med.Chem.Lett.,6,1837,1996). The reaction is usually carried out at room temperature, and for 24-72 hours to produce the methylthiomethyl ether.

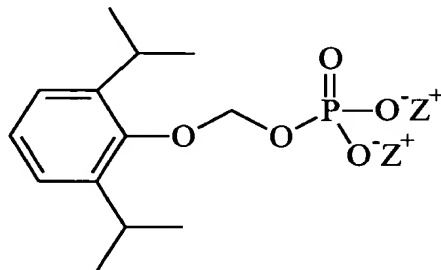
In the second step of the reaction sequence, the methylthiomethyl ether is converted to the corresponding protected phosphonooxymethyl ether. This well-known conversion was successfully applied by Bristol-Myers Squibb for phosphonooxymethylation of taxol (Europ.Pat.0604910A1, Bioorg.Med.Chem.Lett.,6,1837,1996). Thus, a compound of formula III is treated with N-iodosuccinamide and protected phosphoric acid such as dibenzyl phosphate. The reaction is carried out in an inert organic solvent such as tetrahydrofuran and halogenated hydrocarbon such as methylene chloride and in the presence of molecular sieves. Reaction is carried out at room temperature. N-iodosuccinimide and protected phosphoric acid are used in excess (3-5 equivalents) relative to the methylthiomethyl ether.

In the third step of the reaction sequence, the phosphono protecting groups are removed. The deblocking is accomplished by conventional methods well known in the art such as acid- or base-catalyzed hydrolysis, hydrogenolysis, reduction, and the like. For example, catalytic hydrogenolysis can be used to remove the benzyl phosphono-protecting group. Deprotecting methodologies may be found in standard texts, such as T.W. Green and P.G.M. Wutz, Protective groups in organic sythesis, J. Wiley publishers, New York, NY, 1991, pp. 47-67.

The base salts of a compound of formula II may be formed by conventional techniques involving contacting a compound of formula II free acid with a metal base or

particular compound employed. Thus a compound of the formula II may be administrated via any suitable route of administration, preferable parenterally; the dosage may be, for example, in the range of about 0.1 to about 100 mg/kg of body weight, or about 5 to 500 mg/m². Compounds of formula II may also be administrated orally; oral dosage may be in the range of about 5 to about 500 mg/kg of body weight. The actual dose used will vary according to the particular composition of formulated, the route of administration, and the particular site, host and type of tumor being treated. Many factors that modify the action of the drug will be taken into account in determining the dosage including age, sex, diet and the physical conditions of the patient.

Another example is the propofol prodrug according to formula I of the present invention. The structure of the propofol prodrug is shown below:



Propofol Prodrug

In the above formula for the propofol prodrug, Z is the same as defined above for formula II. Therefore, an anesthesiologist skilled in the art of anesthesia will be able to ascertain, without undue experimentation, an appropriate treatment protocol for administering a compound of the present invention. The dosage, mode and schedule of administration of compounds of this invention are not particularly restricted, and will vary with the particular compound employed. Thus, a compound of

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formula I such as the propofol prodrug may be administered via any suitable route of administration, preferably parenterally; the dosage may be, for example, in the range of 0.5 to 10 mg/kg administered according to procedures for induction of general anesthesia or maintenance of general anesthesia. Alternatively, the compound of formula I may be administered by parenteral infusion, the dosage may be, for example, in the range of 2µg/kg/min to 800µg/kg/min administered according to procedures for maintenance of general anesthesia, initiation and maintenance of MAC sedation or initiation and maintenance of ICU sedation.

The present invention also provides pharmaceutical compositions containing a pharmaceutically effective amount of compound of formula I in combination with one or more pharmaceutically acceptable carriers, excipients, diluents or adjuvants. For example, compounds of the present invention may be formulated in the form of tablets, pills, powder mixtures, capsules, injectables, solutions, suppositories, emulsions, dispersions, food premix, and in other suitable forms. They may also be manufactured in the form of sterile solid compositions, for example, freeze-dried and, if desired, combined with other pharmaceutically acceptable excipients. Such solid compositions can be reconstituted with sterile water, physiological saline, or a mixture of water and an organic solvent, such as propylene glycol, ethanol, and the like, or some other sterile injectable medium immediately before use of parenteral administration.

Typical of pharmaceutically acceptable carriers are, for example, manitol, urea, dextrans, lactose, non-reducing sugars, potato and maize starches, magnesium stearate, talc, vegetable oils, polyalkylene glycols, ethyl cellulose, poly(vinyl-pyrrolidone), calcium

carbonate, ethyloleate, isopropyl myristate, benzyl benzoate, sodium carbonate, gelatin, potassium carbonate, silicic acid. The pharmaceutical preparation may also contain non toxic auxiliary substances such as
5 emulsifying, preserving, wetting agents, and the like as for example, sorbitan monolaurate, triethanolamine oleate, polyoxyethylene monostearate, glyceryl tripalmitate, dioctyl sodium sulfosuccinate, and the like.

10 In the following experimental procedures, all temperatures are understood to be in Centigrade (C) when not specified. The nuclear magnetic resonance (NMR) spectral characteristics refer to chemical shifts (δ) expressed in parts per million (ppm) versus
15 tetramethylsilane (TMS) as reference standard. The relative area reported for the various shifts in the proton NMR spectral data corresponds to the number of hydrogen atoms of a particular functional type in the molecule. The nature of the shifts as to multiplicity is
20 reported as broad singlet (bs), broad doublet (bd), broad triplet (bt), broad quartet (bq), singlet (s), multiplet (m), doublet (d), quartet (q), triplet (t), doublet of doublet (dd), doublet of triplet (dt), and doublet of quartet (dq). The solvents employed for taking NMR
25 spectra are acetone-d₆ (deuterated acetone) DMSO-d₆ (perdeuterodimethylsulfoxide), D₂O (deuterated water), CDCl₃ (deuteriochloroform) and other conventional deuterated solvents.

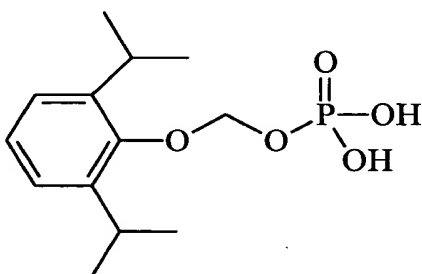
The abbreviations used herein are conventional
30 abbreviations widely employed in the art. Some of which are: MS (mass spectrometry); HRMS (high resolution mass spectrometry); Ac (acetyl); Ph (phenyl); FAB (fast atom bombardment); min (minute); h or hrs (hour(s)); NIS (N-

iodosuccinimide); DMSO (dimethylsulfoxide); THF (tetrahydrofuran).

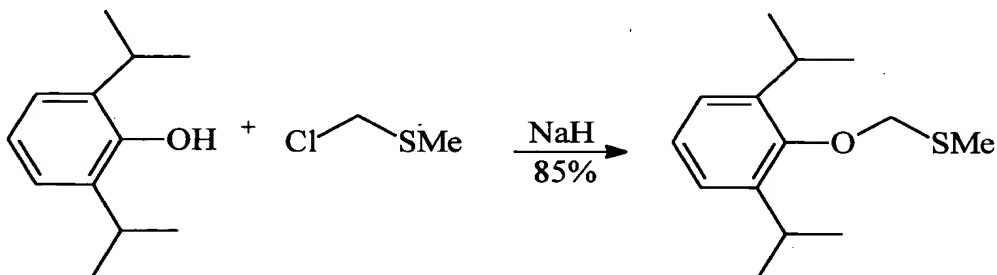
The following examples are provided to illustrate the synthesis of representative compounds of the instant invention and are not to be construed as limiting the scope of the invention in any manner. One skilled in the art will be able to adapt these methods, without undue experimentation, to the synthesis of compounds within the scope of this invention but not specifically disclosed. For example, in the following examples, specific salts are employed, however, these salts are not to be construed as limiting. An example of this situation is the repeated use of a silver salt of dibenzylphosphate. Tetraalkyl ammonium salts, such as tetramethyl ammonium salts or other alkali metal salts may be used in lieu of the silver salt.

EXAMPLES

I. Synthesis of O-Phosphonoxymethylpropofol



Ia. Synthesis of O-methylthiomethylpropofol:

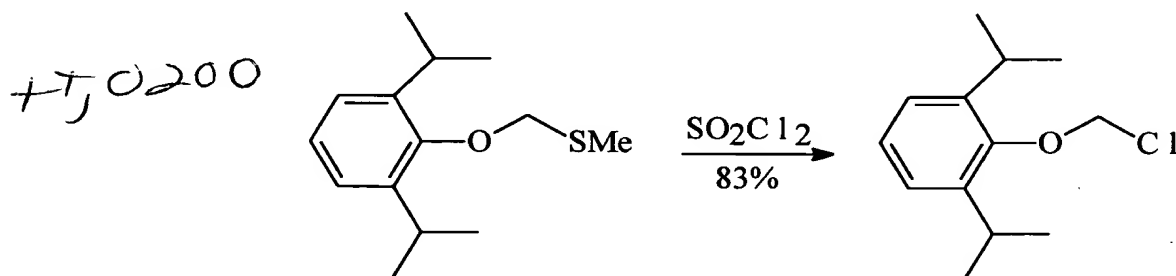


To a stirred suspension of sodium hydride (150 mg, 6.2 mmol) in dry HMPA (10 mL), kept under an argon atmosphere, was added dropwise propofol (1.1 mL of 97%, 5.7 mmol) over 15 minutes. The reaction mixture was then stirred at room temperature for an additional 30 minutes. To this mixture was added dropwise chloromethyl methyl sulfide (550 μ l of 95%, 6.2 mmol) and then stirred at room temperature. After 20 hours, the reaction mixture was partitioned with stirring between water (10 mL) and benzene (20 mL). The aqueous layer was separated and extracted with benzene (10 mL). The benzene fractions were combined, washed with water (2 x 3 mL), dried over sodium sulfate, and evaporated under reduced pressure. The resulting oily residue was subjected to column chromatography (silica gel, hexane, then 4:1 hexane/chloroform) to give 1.15 g (85% yield) of the title compound as a colorless oil.

EIMS: [M+], m/z 238.

^1H NMR (300 MHz, CDCl_3 , δ): 1.24 (d, $J = 6.9$ Hz, 12H), 2.37 (s, 3H), 3.37 (hept, $J = 6.9$ Hz, 2H), 4.86 (s, 2H), 7.12 (s, 3H). ^{13}C NMR (75 MHz, CDCl_3 , δ): 15.40, 23.98, 26.68, 78.12, 124.04, 125.05, 141.74, 152.20.

Ib. Synthesis of O-chloromethylpropofol:

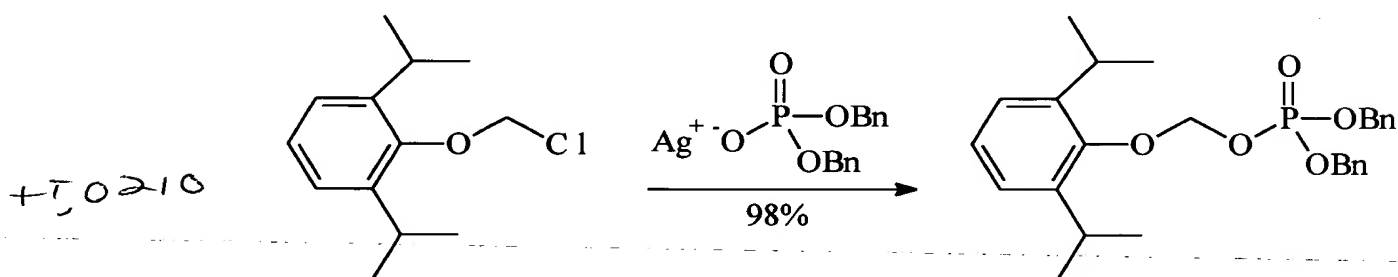


To a stirred solution of O-methylthiomethylpropofol (3.00 g, 12.5 mmol) in dry methylene chloride (30 mL), kept under an argon atmosphere, was added a 1M solution of SO₂Cl₂ in dry methylene chloride (12.2 mL, 12.2 mmol) at 5°C over five minutes. The reaction mixture was stirred for 10 minutes at the same temperature and then for three hours at room temperature. The solvent was evaporated under reduced pressure and the brown residual oil was purified by flash column chromatography (silica gel, 1:20 hexane / ethyl acetate) to give 2.36 g (83% yield) of the title compound as a yellow oil.

CIMS (NH₃): [M]⁺, m/z 226, [MH+ NH₃]⁺, m/z 244.

¹H NMR (300 MHz, CDCl₃, δ): 1.22 (d, J = 6.9 Hz, 12H), 3.35 (hept, J = 6.9 Hz, 2H), 5.76 (s, 2H), 7.15 (m, 3H). ¹³C NMR (75 MHz, CDCl₃, δ) 23.93, 26.84, 83.34, 124.34, 125.95, 141.34, 150.93.

Ic. Synthesis of O-phosphonoxymethylpropofol dibenzyl ester (route-1):



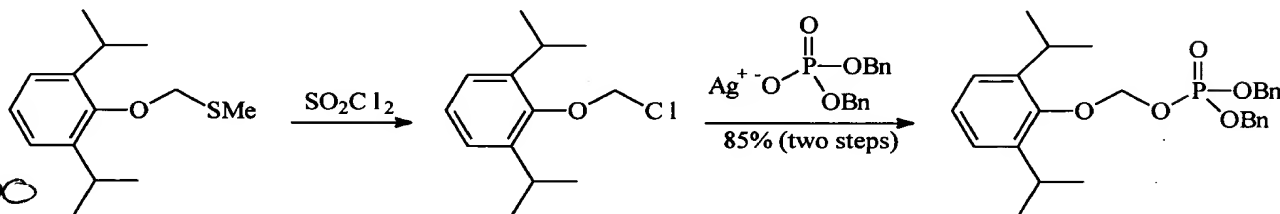
A mixture of O-chloromethylpropofol (2.20 g, 9.7 mmol), silver dibenzylphosphate (3.85 g, 10.0 mmol) and dry toluene (50 mL) was refluxed under an argon atmosphere for 45 minutes. The mixture was cooled down to room temperature and filtered. After the solvent was evaporated *in vacuo*, the oily residue was purified by silica gel

flash column chromatography (9:1 hexane/ethyl acetate and then 1:1 hexane/ethyl acetate) to give 4.43 g (98% yield) of the title compound as a yellow oil.

CIMS (NH₃): [MH]⁺, m/z 469, [MH+ NH₃]⁺, m/z 486.

5 ¹H NMR (300 MHz, CDCl₃, δ): 1.17 (d, J = 6.8 Hz, 12H), 3.33 (hept, J = 6.9 Hz, 2H), 5.00 (d, J = 7.8 Hz, 2H), 5.01 (d, J = 7.8 Hz, 2H), 5.42 (d, J = 9.9 Hz, 2H), 7.12 (m, 3H), 7.32 (m, 1OH). ¹³C NMR (75 MHz, CDCl₃, δ): 23.79, 26.57, 69.15, 69.23, 94.14, 94.20, 124.07, 125.62, 127.70,
10 128.44, 135.42, 135.51, 141.50, 151.07.

1c. Synthesis of O-phosphonoxymethylpropofol dibenzyl ester (alternate route-1):

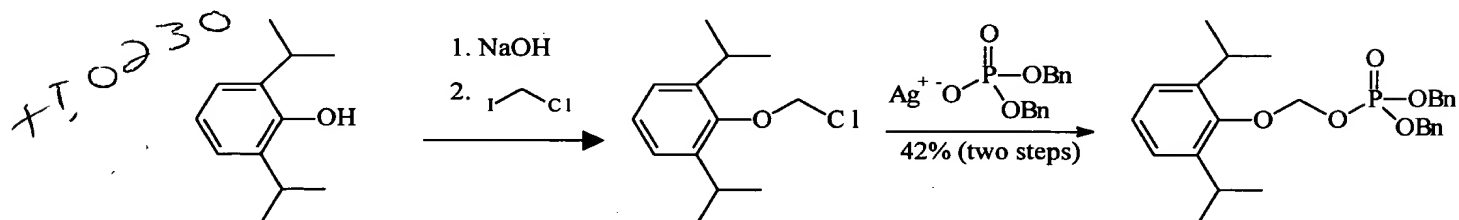


To a stirred solution of O-methylthiomethylpropofol (1.45 g, 6.08 mmol) in dry methylene chloride (15 mL)
15 under an argon atmosphere at 0-5°C was added a 1M solution of SO₂Cl₂ in dry methylene chloride (6.5 mL, 6.5 mmol) over five minutes. The reaction mixture was stirred for 10 minutes at 5°C and three hours at room temperature. Then the solvent was evaporated under reduced pressure. The
20 residual oil was dissolved in toluene (ACS-grade, 20 mL); silver dibenzylphosphate (3.50 g, 9.1 mmol) was added, and the resulting mixture was refluxed for 45 minutes. The brown reaction mixture was cooled down to room temperature and filtered. After the solvent was evaporated *in vacuo*,
25 the oily residue was purified by silica gel flash column chromatography (9:1 hexane/ethyl acetate, then 1:1

hexane/ethyl acetate) to give 2.41 g (85% yield) of the title compound as a yellow oil. This product had the same R_f (TLC) and ¹H NMR spectrum (300 MHz, CDCl₃) as an authentic sample.

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Ic. Synthesis of O-phosphonoxymethylpropofol dibenzyl ester (alternate route-2):



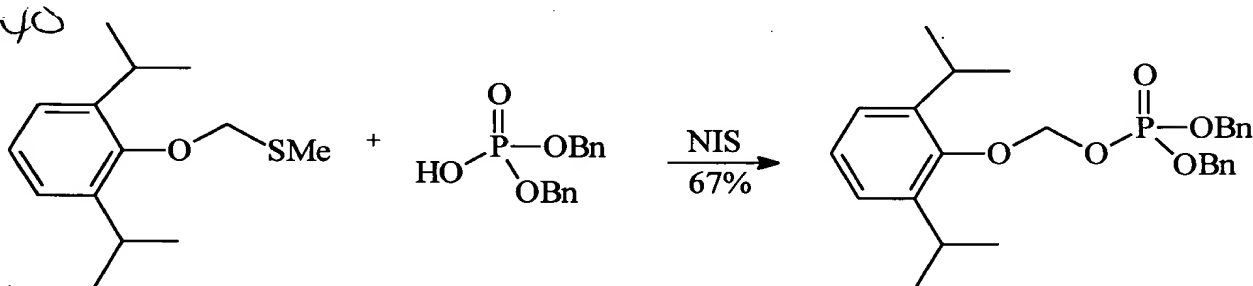
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To a stirred suspension of sodium hydride (41 mg of 60% dispersion in mineral oil, 1.02 mmol) in dry dimethoxyethane (1.5 mL) under an argon atmosphere was added dropwise propofol (200 μl of 97%, 1.04 mmol) over 5 minutes and the resulting mixture was stirred for an additional 15 minutes. The resulting homogeneous solution was added dropwise to a stirred solution of chloriodomethane (4.0 mL, 53 mmol) in dry dimethoxyethane (4 mL) over 15 minutes. This reaction mixture was stirred for two hours, filtered, and then the solvent and the excess of chloriodomethane were evaporated. The residual oil was dissolved in toluene (HPLC-grade, 10 mL). To this solution was added silver dibenzylphosphate (400 mg, 1.04 mmol), and the resulting mixture was refluxed for 10 minutes. After the reaction mixture was cooled down to room temperature and filtered, the solvent was evaporated *in vacuo*. The oily residue was purified by silica gel flash column chromatography (9:1 hexane/ethyl acetate and then 1:1 hexane/ethyl acetate) to give 205 mg (42% yield) of the title compound as a yellow oil. This product had

the same R_f (TLC) and ¹H NMR spectrum (300 MHz, CDCl₃) as an authentic sample.

Further to the above reaction Ic (alternate route-2) it is understood that other reagents may be used depending on the desired compound. For example, when, a compound of
5 formula I wherein n=2 is desired, the chloriodomethane may be substituted with a compound such as X-CH₂-O-CH₂-Cl, wherein X is a good leaving group.

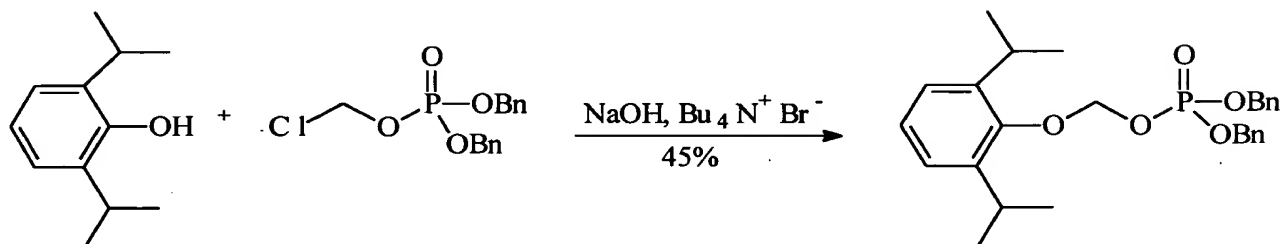
10 **Ic. Synthesis of O-phosphonoxymethylpropofol dibenzyl ester (alternate route-3):**



To a stirred solution of O-methylthiomethylpropofol (91 mg, 0.38 mmol) in dry methylene chloride (2 mL) under an argon atmosphere were added powdered, activated 4Å
15 molecular sieves (100 mg), and then a solution of dibenzylphosphate (127 mg, 0.45 mmol) and N-iodosuccinimide (102 mg of 95%, 0.43 mmol) in tetrahydrofuran (2 mL). The reaction mixture was stirred at room temperature for one hour, filtered, and diluted
20 with methylene chloride (30 mL). The resulting solution was washed with a solution of sodium thiosulfate (2 mL of a 1M solution), a saturated solution of sodium bicarbonate (3 mL), brine (5 mL), dried over a mixture of sodium sulfate and magnesium sulfate, filtered, and concentrated
25 in vacuo. The oily residue was purified by silica gel flash column chromatography (1:1 hexane/ethyl acetate) to give 120 mg (67% yield) of the title compound as a yellow

oil. This product had the same R_f (TLC) and ^1H NMR spectrum (300 MHz, CDCl_3) as an authentic sample.

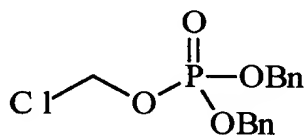
Ic. Synthesis of O-phosphonomoxymethylpropofol dibenzyl



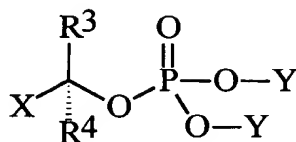
ester (alternate route-4):

To a solution of propofol (38 mg of 97%, 0.21 mmol) in methylene chloride (1 mL) was added tetrabutylammonium bromide (10 mg, 0.03 mmol) and a solution of sodium hydroxide (40 mg, 1 mmol) in water (0.2 mL). The heterogeneous mixture was stirred for 15 minutes. Then a solution of chloromethyl dibenzylphosphate (104 mg, 0.32 mmol) in methylene chloride (1 mL) was added and the reaction mixture was stirred vigorously for eight hours. The mixture was then diluted with methylene chloride (10 mL), washed with water (2 mL), dried over sodium sulfate, filtered, and evaporated in vacuo. The oily residue was purified by silica gel flash column chromatography (hexane, 20:1 hexane/ethyl acetate, and 10:1 hexane/ethyl acetate) to give 44 mg (45% yield) of the title compound as a yellow oil. This product had the same R_f (TLC) and ^1H NMR spectrum (300 MHz, CDCl_3) as an authentic sample.

Further to the above reaction Ic (alternate route-4) it is to be understood that the reagent:

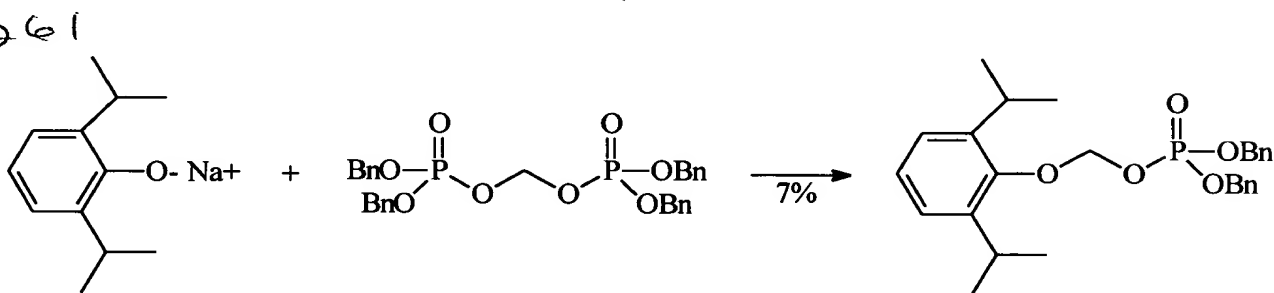


can be generically represented by the following formula:



wherein X represents a leaving group, R³ and R⁴ are each a hydrogen atom, an organic group or an inorganic group and Y is a phosphate protecting group. Examples of leaving groups include chlorine, bromine, iodine, tosylate or any other suitable leaving group. Examples of phosphate protecting groups include protecting groups that temporarily block the reactivity of the phosphate group and permit selective displacement with the nucleophilic displacement reaction. Examples of such blocking groups include but are not limited to benzyl, allyl, tertiary butyl and isopropyl, ethyl and β-cyanoethyl.

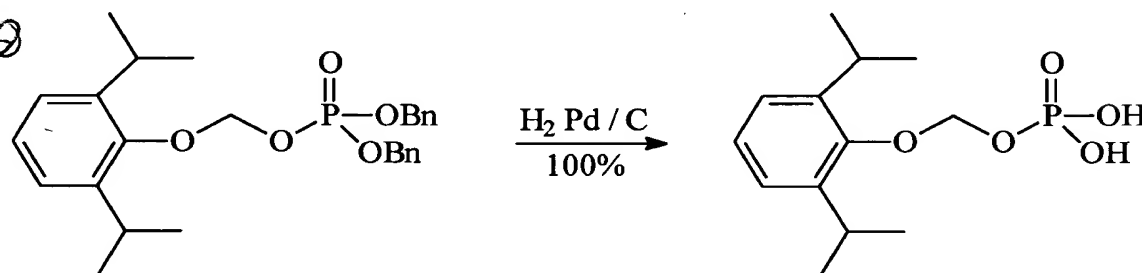
15 **Ic. Synthesis of O-phosphonooxymethylpropofol dibenzyl ester (alternate route-5):**



To a stirred suspension of sodium hydride (36 mg of a 60% dispersion in mineral oil, 0.91 mmol) in dry dimethoxyethane (2 mL) under an argon atmosphere was added dropwise propofol (172 μl of 97%, 0.90 mmol) over five minutes. The resulting mixture was stirred at room temperature for an additional 20 minutes. To the mixture was then added the solution of formaldehyde bis-(dibenzylphosphono)acetal (500 mg, 0.88 mmol) in dry

dimethoxyethane (3 mL). The reaction mixture was stirred at room temperature for 20 hours and then at 70°C for 2.5 hours. The mixture was then filtered and the solvent was evaporated *in vacuo*. The oily residue was purified by silica gel flash column chromatography (hexane, 10:1 hexane/ethyl acetate, and then 1:1 hexane/ethyl acetate) to give 29 mg (7% yield) of the title compound as a yellow oil. This product had the same R_f (TLC) and ^1H NMR spectrum (300 MHz, CDCl_3) as an authentic sample.

10 **Id. Synthesis of O-phosphonooxymethylpropofol:**

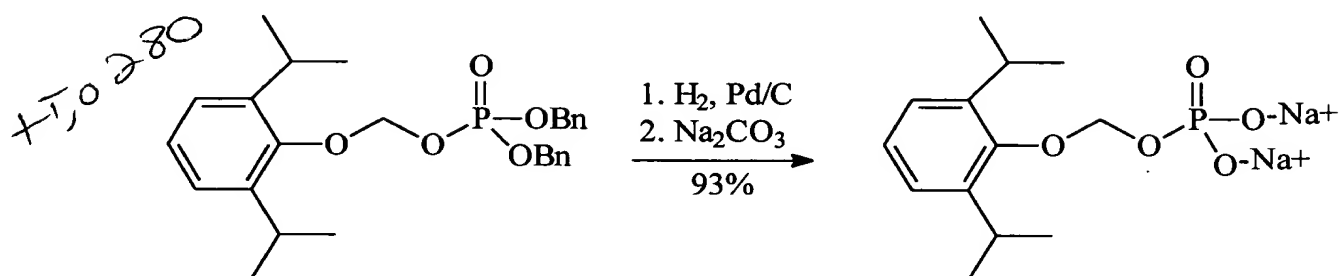


To a solution of O-phosphonooxymethylpropofol dibenzyl ester (115 mg, 0.245 mmol) in methanol (10 mL) was added palladium on carbon (10%, 20 mg). This mixture was stirred under an atmosphere of hydrogen (1 atm) for 1.5 hour. The catalyst was removed by filtration through Celite, and the filtrate was evaporated at reduced pressure to give 70.5 mg (100% yield) of the title compound as a colorless oil, unstable on standing at room temperature.

20 FABMS-(GLY): $[\text{M}-\text{H}]^-$, m/z 287.

^1H NMR (300 MHz, acetone- d_6 , δ): 1.19 (d, $J = 6.8$ Hz, 12H), 3.46 (sext, $J = 6.8$ Hz, 2H), 5.45 (d, $J = 9.7$ Hz, 2H), 7.15 (m, 3H). ^{13}C NMR (75 MHz, acetone- d_6 , δ): 24.2178, 27.1496, 94.63, 94.65, 124.08, 126.30, 142.46, 152.32.

Ie. Synthesis of O-phosphonooxymethylpropofol disodium salt:

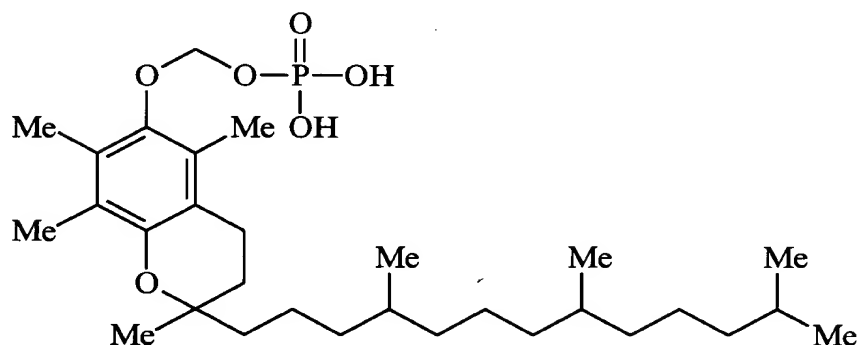


To a solution of O-phosphonooxymethylpropofol dibenzyl ester (1.05 g, 2.24 mmol) in tetrahydrofuran (100 mL) was added water (5 mL) and palladium on carbon (10%, 300 mg). This mixture was stirred under hydrogen (1 atm) for one hour. The catalyst was removed by filtration through Celite, and the filtrate was treated with a solution of sodium carbonate hydrate (263 mg in 3 mL of water, 2.12 mmol). THF was evaporated under reduced pressure and the residual water solution was extracted with ether (3 x 3 mL). The aqueous layer was evaporated to dryness (argon stream or rotary evaporator) and the resulting solid was dried overnight *in vacuo*, washed with ether (4 x 4 mL), hexane (2 x 4 mL), and again dried *in vacuo* to provide 655 mg (93% yield) of the title compound as a white powder.

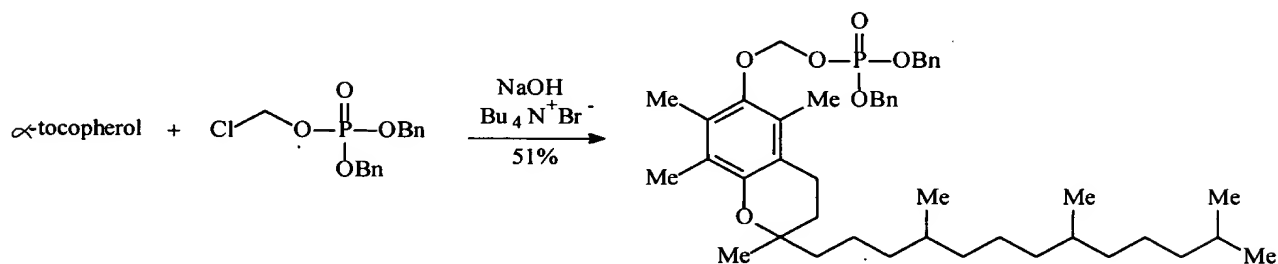
FABMS-(GLY): [M-2Na+H]⁻, m/z 287.

¹H NMR (300 MHz, D₂O, δ): 1.22 (d, J = 7.0 Hz, 12H), 3.46 (hept, J = 6.9 Hz, 2H), 5.27 (d, J = 7.5 Hz, 2H), 7.28 (m, 3H).

II. Synthesis of O-Phosphonoxymethyl-alpha-tocopherol



IIa. Synthesis of O-phosphonoxymethyl-alpha-tocopherol dibenzyl ester:



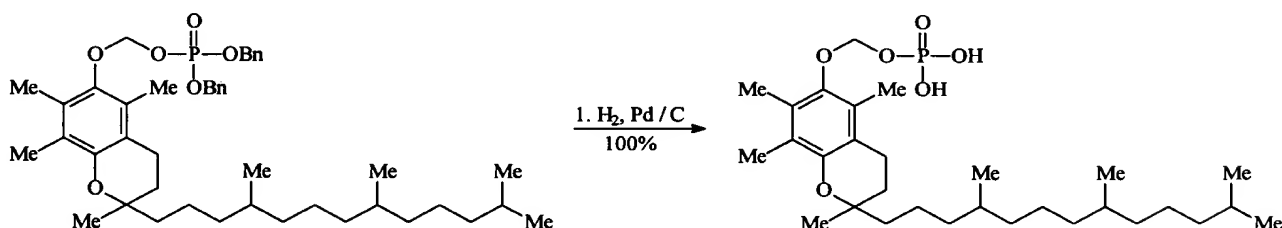
To a solution of chloromethyl dibenzylphosphate (323 mg, 0.98 mmol), alphas-tocopherol (409 mg of 97%, 0.92 mmol), and tetrabutylammonium bromide (301 mg, 0.92 mmol) in benzene (5 mL) was added an aqueous solution of sodium hydroxide (150 mg in 0.2 mL of water, 3.7 mmol). The resulting reaction mixture was vigorously stirred at room temperature for two hours under an argon atmosphere. The mixture was then diluted with benzene (10 mL), washed with water (3 x 3 mL), dried over magnesium sulfate, filtered, and evaporated under reduced pressure. The brown oily residue was purified by silica gel flash column chromatography (10:1 hexane/ethyl acetate) to give 336 mg (51 % yield) of the title compound as a yellow oil.

FABMS+(NBA): [M]⁺, m/z 720.

¹H NMR (500 MHz, CDCl₃, δ): 0.85 (m, 12H), 1.21 (s, 3H), 1.27 (m, 24H), 1.75 (m, 2H), 2.06 (s, 3H), 2.11 (s, 3H), 2.14 (s, 3H), 2.54 (t, J = 6.8 Hz, 2H), 4.97 (m, 4H), 5.20 (d, J = 9.3 Hz, 2H), 7.31 (m, 10H).

+T, 0300

5 **IIb. Synthesis of O-phosphonooxymethyl- α -tocopherol:**

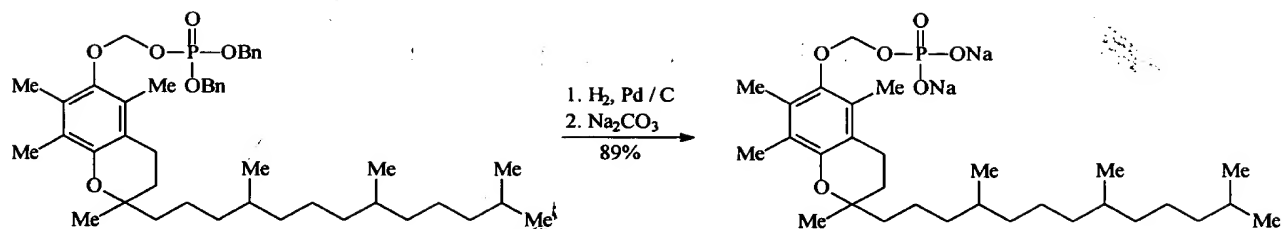


To a solution of O-phosphonooxymethyl- α -tocopherol dibenzyl ester (88 mg, 0.12 mmol) in tetrahydrofuran (10 mL) was added palladium on carbon (10%, 15 mg). The mixture was stirred under an atmosphere of hydrogen (1 atm) for 10 minutes (the reaction was complete after 5 minutes as judged by TLC). The catalyst was removed by filtration through Celite, the filtrate was evaporated at reduced pressure, and then dried *in vacuo*. The title compound was obtained in an amount of 70 mg (100% yield) as a brownish oil, which was unstable at room temperature.

FABMS+(NBA): [M]⁺, m/z 540, [M + Na]⁺, m/z 563; (NBA + Li): [M + Li]⁺, m/z 547

20 **IIc. Synthesis of O-phosphonooxymethyl- α -tocopherol disodium salt:**

+T, 0301



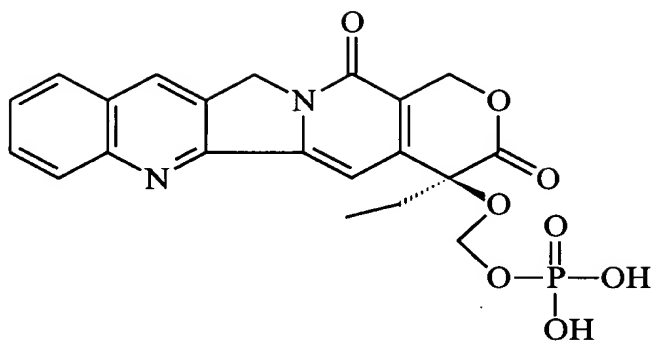
To a solution of O-phosphonooxymethyl- α -tocopherol dibenzyl ester (100 mg, 0.14 mmol) in tetrahydrofuran (10 mL) was added palladium on carbon (10%, 18 mg). The mixture was stirred under an atmosphere of hydrogen (1 atm) for 5 minutes. The catalyst was removed by filtration through Celite, the filtrate was evaporated at room temperature at reduced pressure, and the resulting residue was dissolved in ether (2 mL). The ether solution was then treated with an aqueous solution of sodium hydroxide (11.2 mg in 100 mL of water, 0.28 mmol), and the resulting mixture was stirred at room temperature for 10 min. The ether phase was removed and the aqueous phase was washed with ether (3 x 3 mL) and then dried *in vacuo* for 20 hours to give 73 mg (89% yield) of the title compound as a gray solid.

FABMS+(TG/G): $[\text{MH}]^+$, m/z 585, $[\text{M} + \text{Na}]^+$, m/z 607

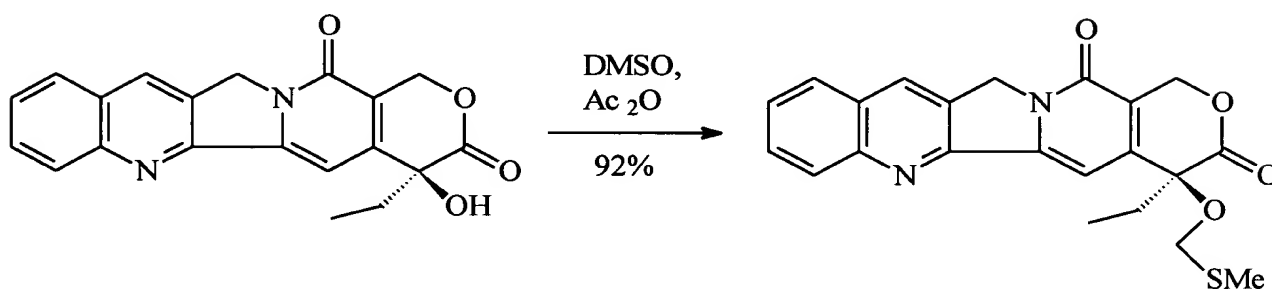
The synthesis of water soluble derivatives of camptothecin will also be further detailed as follows:

III. Synthesis of 20-O-Phosphonooxymethylcamptothecin

+T, 0310



IIIa. Synthesis of 20-O-methylthiomethylcamptothecin:



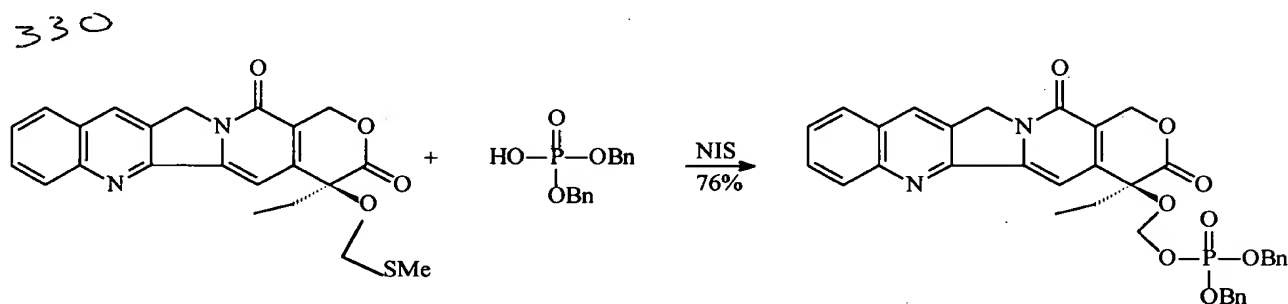
To a suspension of camptothecin (5.0 g, 14.3 mmol) in dimethylsulfoxide (250 mL) was added acetic anhydride (125 mL) and acetic acid (35 mL). The heterogeneous mixture was vigorously stirred at room temperature for 24 hours, poured into ice (800 mL), stirred for 30 minutes, and then extracted with methylene chloride (4 x 100 mL). The combined methylene chloride extracts were washed with water (2 x 100 mL) and dried over magnesium sulfate. The methylene chloride was removed at reduced pressure to give a brownish solid. The solid was dissolved in a minimum volume of methylene chloride. This solution was filtered and diluted with a 10-fold excess of hexane and then kept overnight in the refrigerator. The precipitated solid was filtered off, washed several times with hexane, and dried to give 5.38 g (92% yield) of the title compound as a light brown powder. $\alpha_{20}^{D_{123.6}}$ (c 0.55, CHCl_3).

FABMS+(NBA): $[\text{MH}]^+$, m/z 409.

¹H NMR (400 MHz, CDCl₃, δ): 0.93 (t, *J* = 7.2 Hz, 3H), 2.11 (sext, *J* = 7.6 Hz, 1H), 2.29 (sext, *J* = 7.6 Hz, 1H), 2.30 (s, 3H), 4.58 (s, 2H), 5.33 (s, 2H), 5.40 (d, *J* = 17.2 Hz, 1H), 5.62 (d, *J* = 17.3 Hz, 1H), 7.48 (s, 1H), 7.69 (t, *J* = 7.1 Hz, 1H), 7.86 (t, *J* = 7.1 Hz, 1H), 7.96 (d, *J* = 8.1 Hz, 1H), 8.25 (d, *J* = 8.5 Hz, 1H), 8.42 (s, 1H).

¹³C NMR (75 MHz, CDCl₃, δ): 7.76, 14.89, 33.90, 49.92, 66.68, 71.02, 76.57, 97.51, 122.63, 128.02, 128.09, 128.30, 129.71, 130.64, 131.11, 145.14, 146.10, 148.88, 152.27, 157.43, 169.34, 169.73.

IIIb. Synthesis of 20-O-phosphonoxymethylcamptothecin dibenzyl ester:



To a well stirred suspension of 20-O-methylthiomethylcamptothecin (1.00 g, 2.44 mmol) and powdered, activated 4 Å molecular sieves (5 g) in tetrahydrofuran (20 mL) was added a suspension of N-iodosuccinimide (2.00 g of 95%, 8.44 mmol) and dibenzylphosphate (2.20 g, 7.83 mmol) in methylene chloride (12 mL). The resulting mixture was vigorously stirred at room temperature for 30 minutes, filtered, and diluted with ethyl acetate (300 mL). The solution was washed with aqueous sodium thiosulfate (10%, 2 x 15 mL), water (2 x 20 mL), brine (50 mL), and dried over magnesium sulfate. The mixture was filtered and the solvent was evaporated under reduced pressure. The brown oily residue

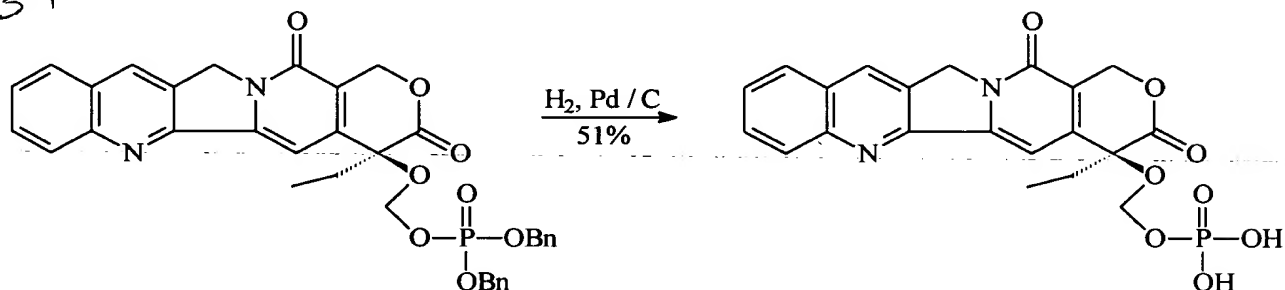
was purified by silica gel flash column chromatography (98:2 ethyl acetate/methanol) and dried *in vacuo* overnight to give 1.19 g (76% yield) of the title compound as a yellow foam. $\alpha_{D_{20}}^{20} -43.1^\circ$ (c 0.55, CHCl_3).

5 FABMS+(NBA): $[\text{MH}]^+$, m/z 639.

^1H NMR (400 MHz, CDCl_3 , δ): 0.91 (t, $J = 7.4$ Hz, 3H), 2.09 (sext, $J = 7.4$ Hz, 1H), 2.26 (sext, $J = 7.4$ Hz, 1H), 5.06 (m, 4H), 5.28 (m, 3H), 5.35 (d, $J = 17.0$ Hz, 1H), 5.48 (2xd, $J = 10.5$ Hz, 1H), 5.64 (d, $J = 17.3$ Hz, 1H), 7.59 (s, 1H), 7.67 (t, $J = 7.0$ Hz, 1H), 7.80 (t, $J = 7.1$ Hz, 1H), 7.94 (d, $J = 8.0$ Hz, 1H), 8.13 (d, $J = 8.5$ Hz, 1H), 8.35 (s, 1H).

^{13}C NMR (100 MHz, CDCl_3 , δ): 7.73, 29.53, 32.49, 49.86, 66.74, 69.37, 69.44, 78.48, 88.99, 89.04, 98.09, 121.55, 127.65, 127.70, 127.90, 128.01, 128.25, 128.35, 128.36, 129.62, 130.48, 130.97, 135.45, 135.55, 145.47, 145.82, 148.76, 152.15, 157.18, 168.67.

IIIc. Synthesis of 20-O-phosphonoxymethylcamptothecin:



To a solution of 20-O-phosphonoxymethylcamptothecin dibenzyl ester (500 mg, 0.78 mmol) in tetrahydrofuran (100 mL) and water (5 mL) was added palladium on carbon (10%, 500 mg). This mixture was stirred under an atmosphere of

002080" 08E1E160

hydrogen (1 atm) for 35 minutes. The catalyst was removed by filtration through Celite. The Celite was then washed with tetrahydrofuran (300 mL) and the combined filtrates were evaporated at reduced pressure. The resulting green solid was washed with ether (2 x 20 mL), hexane (50 mL), dried in vacuo, and then dissolved in hot methanol (60 mL). The solution was filtered, concentrated at reduced pressure to ~10 mL volume. After standing at room temperature for one hour, the solution was placed in the refrigerator overnight. The crystalline precipitate that had formed overnight was filtered off and dried in vacuo to give 155 mg of the title compound as a yellow solid. The filtrate was concentrated to ~1 mL volume and kept in the refrigerator for one hour to give an additional 28 mg of the product. Total yield: 183 mg (51%).

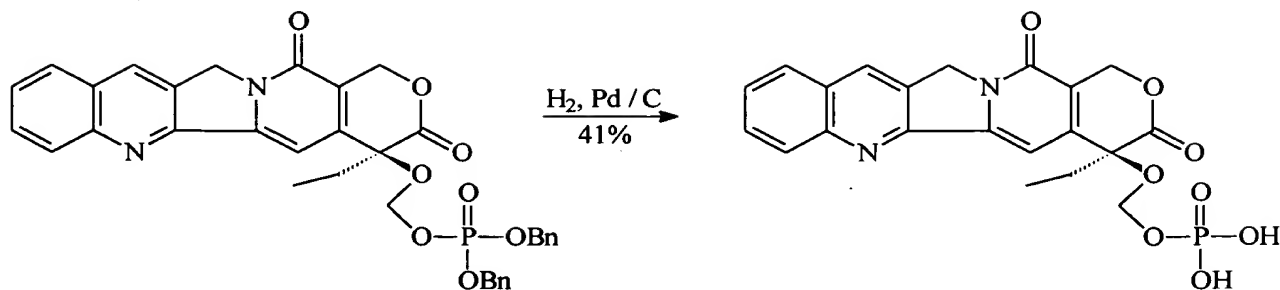
FABMS+(NBA): [MH]⁺, m/z 459, [M + Na]⁺, m/z 481.

¹H NMR (400 MHz, D₂O, δ): 0.95 (t, J = 7.5 Hz, 3H), 2.25 (m, 2H), 4.98 (d, J = 5.0 Hz, 2H), 5.14 (2xd, J = 9.3 Hz, 1H), 5.22 (2xd, J = 8.9 Hz, 1H), 5.48 (d, J = 17.0 Hz, 1H), 5.60 (d, J = 16.9 Hz, 1H), 7.54 (s, 1H), 7.56 (t, J = 7.7 Hz, 1H), 7.77 (t, J = 7.2 Hz, 1H), 7.86 (d, J = 8.2 Hz, 1H), 8.01 (d, J = 8.5 Hz, 1H), 8.44 (s, 1H).

Chemical structure and purity of the product were also confirmed by ¹H NMR spectroscopy of its disodium salt, formed from the acid and two mole equivalents of sodium bicarbonate in D₂O.

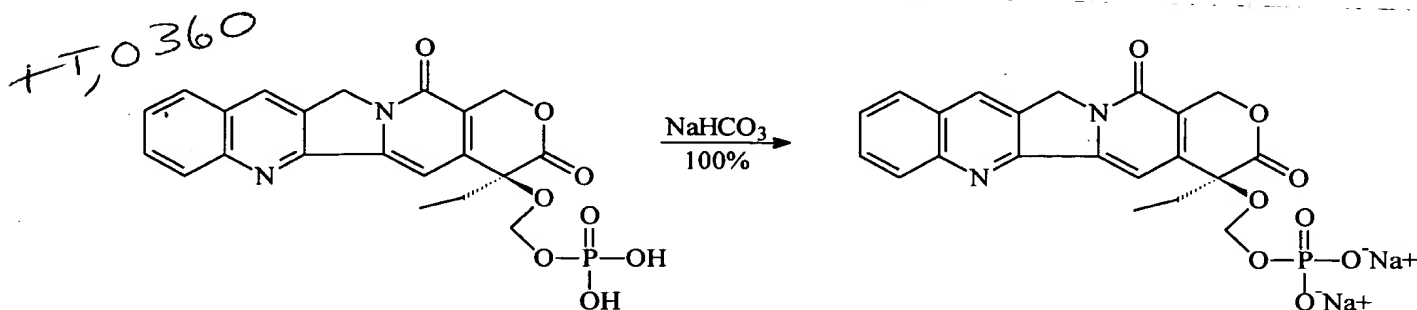
IIIc. Synthesis of 20-O-phosphonoxymethylcamptothecin (alternate run):

HT, 0350



To a solution of 20-O-phosphonooxymethylcamptothecin
 dibenzyl ester (500 mg, 0.78 mmol) in tetrahydrofuran (100
 mL) and water (5 mL) was added palladium on carbon (10 %,
 500 mg). The mixture was stirred under an atmosphere of
 5 hydrogen (1 atm) for 30 minutes. The catalyst was removed
 by filtration through Celite. Celite was washed with
 tetrahydrofuran (2 x 100 mL), and the combined filtrates
 were treated with an aqueous solution of sodium carbonate
 hydrate (97 mg in 2 mL water, 0.78 mmol). THF was
 10 evaporated at reduced pressure and the heterogeneous
 aqueous residue was diluted with water (10 mL) and
 extracted with ethyl acetate (2 x 3 mL). The resulting
 yellow homogeneous solution was acidified with
 hydrochloric acid (10%) to pH=1. The resulting precipitate
 15 was filtered off and dried in vacuo overnight to give 145
 mg (41% yield) of the title compound as a yellow solid.

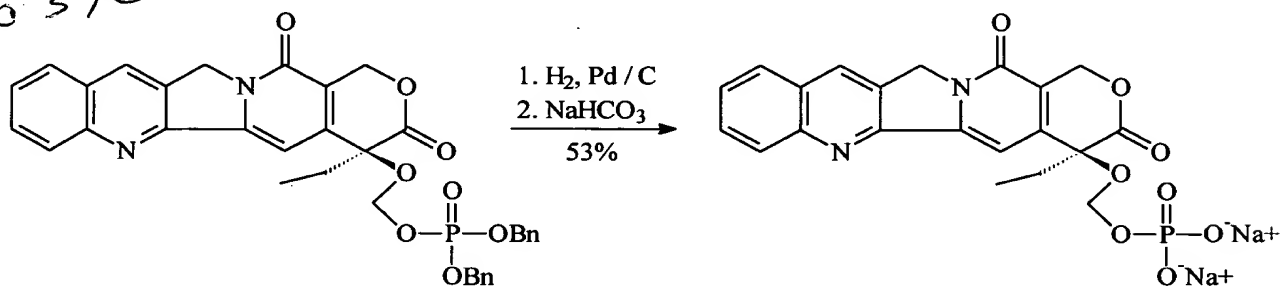
**IIIId. Synthesis of 20-O-phosphonooxymethylcamptothecin
 disodium salt:**



To a suspension of 20-O-phosphonooxymethylcamptothecin (5 mg, 10.9 μmol) in deuterium oxide (0.5 mL) was added a deuterium oxide solution of sodium bicarbonate (50 μl of 0.44 M solution = 22 μmol). The heterogeneous mixture
5 was sonicated for a few minutes to give a yellow homogenous solution of the title product.

^1H NMR (400 MHz, D_2O , after 10 min., 96% lactone, 4% carboxylate, δ): 1.05 (t, $J = 7.2$ Hz, 3H), 2.27 (m, 2H), 4.57 (d, $J = 18.8$ Hz, 1H), 4.70 (d, $J = 18.9$ Hz, 1H), 5.06
10 (dd, $J = 8.3$, $J = 5.4$ Hz, 1H), 5.18 (dd, $J = 7.6$, $J = 5.5$ Hz, 1H), 5.45 (d, $J = 16.7$ Hz, 1H), 5.59 (d, $J = 16.8$ Hz, 1H), 7.34 (t, $J = 7.1$ Hz, 1H), 7.41 (s, 1H), 7.60 (m, 2H), 7.81 (d, $J = 8.3$ Hz, 1H), 8.17 (s, 1H).

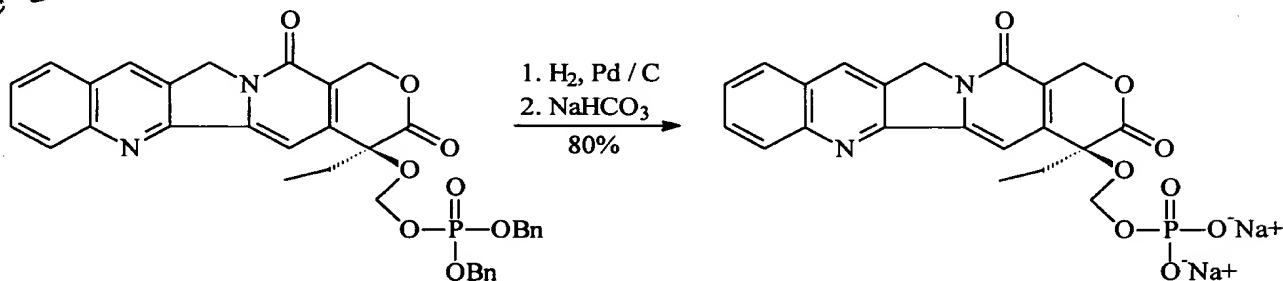
IIId. Synthesis of 20-O-phosphonooxymethylcamptothecin
15 disodium salt (alternate run 1):



To a solution of 20-O-phosphonooxymethylcamptothecin dibenzyl ester (78 mg, 0.122 mmol) in tetrahydrofuran (10 mL) and water (3 mL) was added palladium on carbon (10%, 80 mg). The mixture was stirred under an atmosphere of
20 hydrogen (1 atm) for 30 minutes. The catalyst was removed by filtration through Celite and the filtrate was treated with an aqueous solution of sodium bicarbonate (20 mg in 0.5 mL of water, 0.238 mmol). The yellow precipitate was filtered off, washed with methylene chloride, and dried in

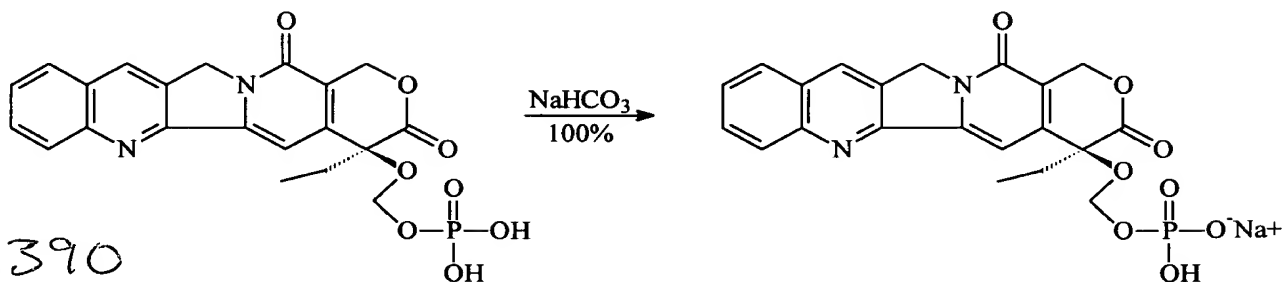
vacuo to give 35 mg (57% yield) of the title compound (light brown solid) as a mixture of its lactone form (82%) and its carboxylate form (18%) (by ^1H NMR).

IIId. Synthesis of 20-O-phosphonooxymethylcamptothecin disodium salt (alternate run 2):



To a solution of 20-O-phosphonooxymethylcamptothecin dibenzyl ester (500 mg, 0.78 mmol) in tetrahydrofuran (100 mL) and water (5 mL) was added palladium on carbon (10%, 500 mg). This mixture was stirred under an atmosphere of hydrogen (1 atm) for 30 minutes. The catalyst was removed by filtration through Celite. Celite was washed with tetrahydrofuran (50 mL), and the combined filtrates were treated with an aqueous solution of sodium carbonate hydrate (90 mg in 2 mL of water, 0.72 mmol). Tetrahydrofuran was evaporated at reduced pressure, and the residue was dissolved in water (15 mL). The heterogeneous mixture was extracted with ethyl acetate (2 x 15 mL) and ether (20 mL) and the resulting aqueous homogenous solution was evaporated to dryness under a stream of argon at room temperature. The residue was dried in vacuo overnight to give 290 mg (80% yield) of the title compound (orange solid) as a mixture of its lactone form (60%), its carboxylate form (40%), and a small amount of byproducts (by ^1H NMR).

IIIe. Synthesis of 20-O-phosphonoxymethylcamptothecin monosodium salt:

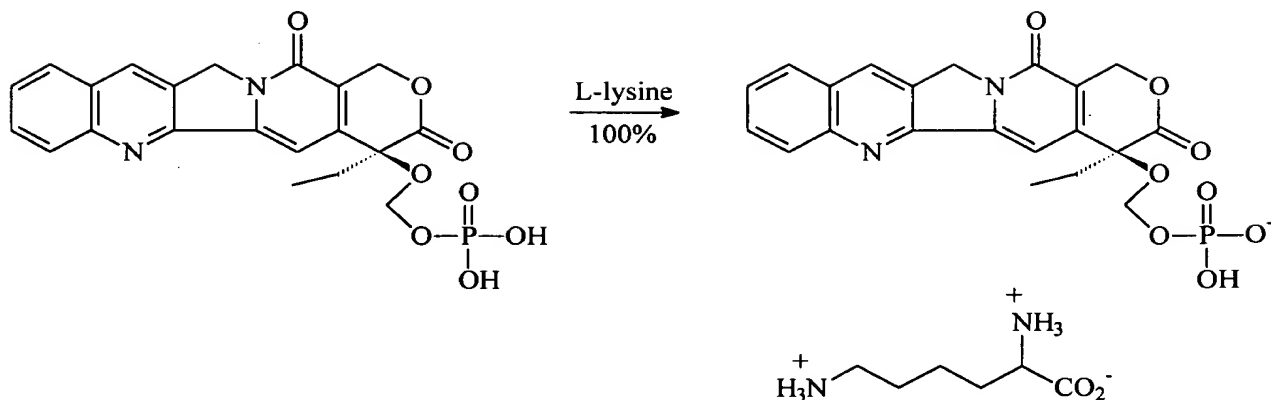


To a continuously sonicated suspension of 20-O-phosphonoxymethylcamptothecin (5 mg, 10 μmol) in 5 deuterium oxide (0.5 mL) was added dropwise a deuterium oxide solution of sodium bicarbonate until complete homogenization was achieved (21 μl of 0.44 M solution = 9.2 μmol). A yellow homogenous solution of the title compound was obtained.

- 10 ^1H NMR (400 MHz, D_2O , δ): 1.00 (t, $J = 7.2$ Hz, 3H), 2.23 (m, 2H), 4.40 (d, $J = 18.8$ Hz, 1H), 4.50 (d, $J = 18.8$ Hz, 1H), 5.10 (dd, $J = 9.7$, $J = 5.9$ Hz, 1H), 5.26 (dd, $J = 9.0$, $J = 6.1$ Hz, 1H), 5.39 (d, $J = 16.7$ Hz, 1H), 5.50 (d, $J = 16.7$ Hz, 1H), 7.20 (t, $J = 7.3$ Hz, 1H), 7.28 (s, 1H),
15 7.46 (m, 2H), 7.66 (d, $J = 8.4$ Hz, 1H), 8.02 (s, 1H).

IIIIf. Synthesis of 20-O-phosphonoxymethylcamptothecin lysine salt:

+T,0391

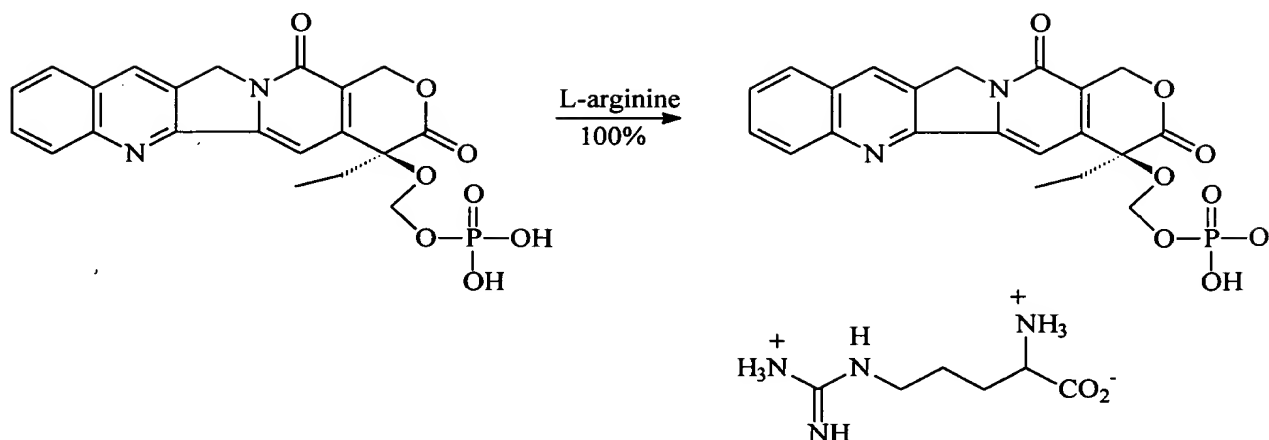


To a continuously sonicated suspension of 20-O-phosphonooxymethylcamptothecin (5 mg, 10 μmol) in deuterium oxide (0.5 mL) was added dropwise a deuterium oxide solution of L-lysine (25 μl of 0.43 M solution = 10.7 μmol) until complete homogenization was achieved. A yellow homogenous solution of the title compound was obtained.

^1H NMR (400 MHz, D_2O , 94% lactone, 6% carboxylate, δ): 1.02 (t, $J = 7.2$ Hz, 1H), 1.49 (m, 2H), 1.73 (m, 2H), 1.88 (m, 2H), 2.25 (m, 2H), 3.03 (t, $J = 7.5$ Hz, 2H), 3.76 (t, $J = 6.0$ Hz, 1H), 4.43 (d, $J = 19.0$ Hz, 1H), 4.52 (d, $J = 18.9$ Hz, 1H), 5.11 (dd, $J = 9.7$, $J = 5.8$ Hz, 1H), 5.27 (dd, $J = 9.2$, $J = 5.8$ Hz, 1H), 5.41 (d, $J = 16.7$ Hz, 1H), 5.53 (d, $J = 16.7$ Hz, 1H), 7.23 (t, $J = 7.4$ Hz, 1H), 7.30 (s, 1H), 7.49 (m, 2H), 7.68 (d, $J = 8.4$ Hz, 1H), 7.04 (s, 1H).

15 IIIg. Synthesis of 20-O-phosphonooxymethylcamptothecin arginine salt:

+T,0400

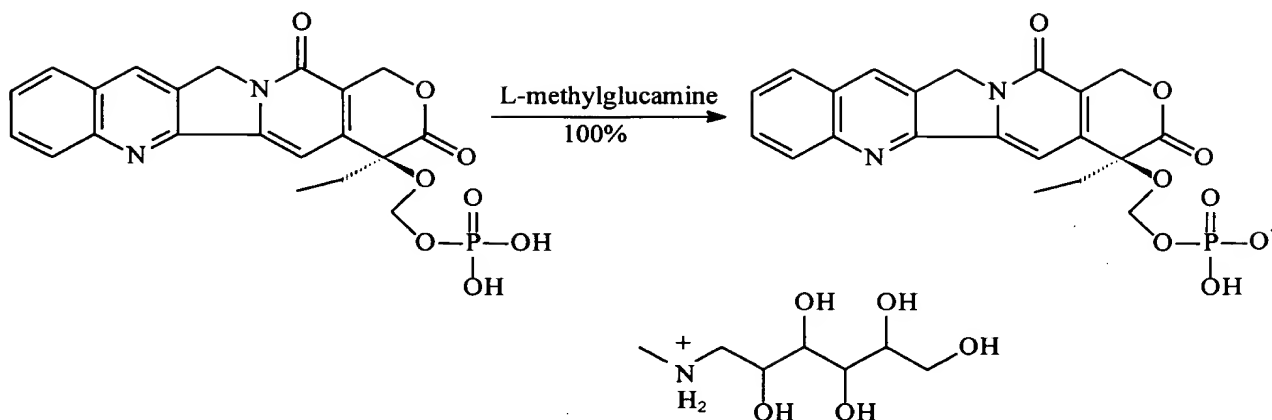


To a continuously sonicated suspension of 20-O-phosphonoxymethylcamptothecin (5 mg, 10 μmol) in deuterium oxide (0.5 mL) was added dropwise a deuterium oxide solution of L-arginine (27 μl of 0.40 M, 10.8 μmol) until complete homogenization was achieved. A yellow homogenous solution of the title compound was obtained.

^1H NMR (400 MHz, D_2O , δ): 1.02 (t, $J = 7.1$ Hz, 1H), 1.66 (m, 2), 1.89 (m, 2H), 2.25 (m, 2H), 3.20 (t, $J = 6.8$ Hz, 2H), 3.77 (t, $J = 6.0$ Hz, 1H), 4.40 (d, $J = 19.0$ Hz, 1H), 4.49 (d, $J = 18.8$ Hz, 1H), 5.12 (dd, $J = 9.7$, $J = 6.0$ Hz, 1H), 5.29 (dd, $J = 8.8$, $J = 6.1$ Hz, 1H), 5.40 (d, $J = 16.7$ Hz, 1H), 5.51 (d, $J = 16.7$ Hz, 1H), 7.20 (t, $J = 7.3$ Hz, 1H), 7.29 (s, 1H), 7.47 (m, 2H), 7.66 (d, $J = 8.3$ Hz, 1H), 8.03 (s, 1H).

15 IIIh. Synthesis of 20-O-phosphonoxymethylcamptothecin N-methylglucamine salt:

+4,0410

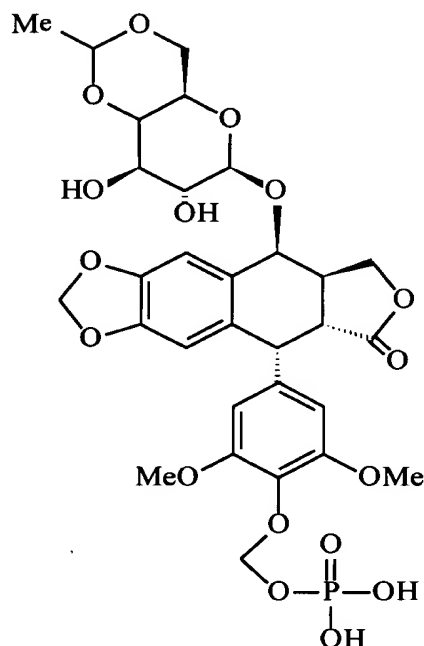


To a continuously sonicated suspension of 20-O-phosphonoxymethylcamptothecin (5 mg, 10.9 μmol) in deuterium oxide (0.5 mL) was added dropwise a deuterium oxide solution of (D)-N-methylglucamine (21 μl of 0.51 M solution = 10.7 μmol) until complete homogenization was achieved. A yellow homogenous solution of the title compound was obtained.

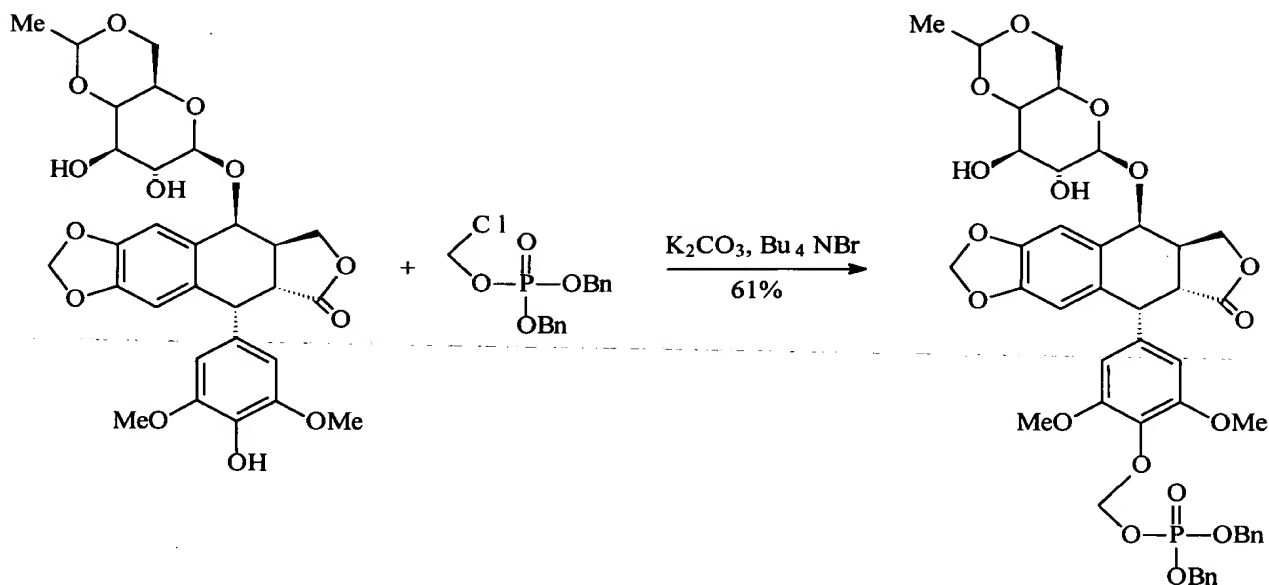
^1H NMR (400 MHz, D_2O , δ): 1.02 (t, $J = 7.3$ Hz, 3H), 2.25 (m, 2H), 2.78 (s, 3H), 3.20 (m, 2H), 3.65 (m, 2H), 3.80 (m, 3H), 4.11 (m, 1H), 4.44 (d, $J = 18.9$ Hz, 1H), 4.53 (d, $J = 19.0$ Hz, 1H), 5.12 (dd, $J = 9.8$, $J = 5.9$ Hz, 1H), 5.27 (dd, $J = 9.2$, $J = 5.9$ Hz, 1H), 5.41 (d, $J = 16.7$ Hz, 1H), 5.53 (d, $J = 16.7$ Hz, 1H), 7.23 (t, $J = 7.4$ Hz, 1H), 7.49 (m, 2H), 7.69 (d, $J = 8.4$ Hz, 1H), 8.05 (s, 1H).

IV. Synthesis of 4'-O-phosphonoxymethyletoposide:

+T, 0430



IVa. Synthesis of 4'-O-phosphonoxymethyletoposide dibenzyl ester:



To a solution of chloromethyl dibenzylphosphate (670 5 mg, 2.05 mmol), etoposide (300 mg, 0.51 mmol), and

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tetrabutylammonium bromide (164.4 mg, 0.51 mmol) in tetrahydrofuran (0.5 mL) was added powdered potassium carbonate (352.4 mg, 2.55 mmol). The resulting reaction mixture was vigorously stirred at room temperature for 35 minutes. The mixture was then directly purified by silica gel flash column chromatography (30:1 methylene chloride/methanol) to give 272 mg (61% yield) of the title compound as a white solid with more than 95% of the trans stereochemistry retained.

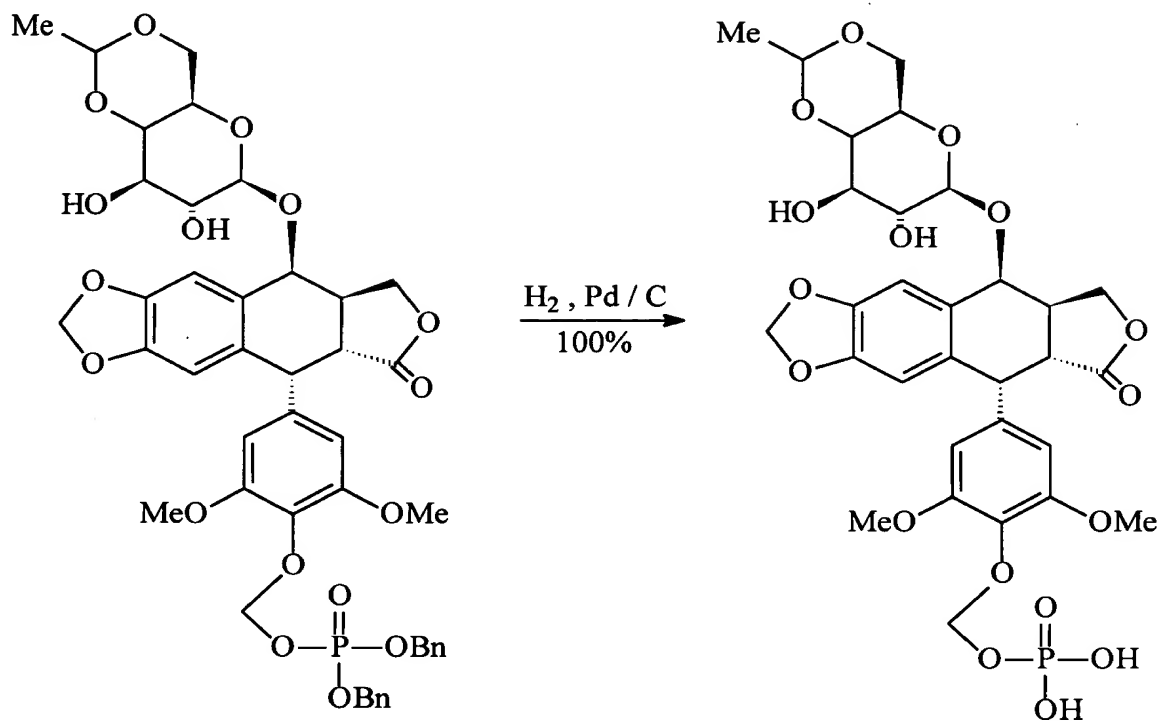
10 FABMS+(NBA): $[MH]^+$, m/z 879.

1H NMR (400 MHz, $CDCl_3$, δ): 1.41 (d, $J = 5.0$ Hz, 3H), 2.79 (br s, 1H), 2.86 (m, 1H), 2.97 (br s, 1H), 3.30 (dd, $J = 14.2$, $J = 5.3$ Hz, 1H), 3.35 (m, 2H), 3.45 (t, $J = 8.5$, $J = 8.0$ Hz, 1H), 3.59 (m, 1H), 3.66 (s, 6H), 3.74 (m, 1H), 4.19 (m, 1H), 4.20 (t, $J = 8.5$, $J = 8.0$ Hz, 1H), 4.42 (dd, $J = 10.3$, $J = 9.1$ Hz, 1H), 4.60 (d, $J = 5.2$ Hz, 1H), 4.64 (d, $J = 7.6$ Hz, 1H), 4.76 (q, $J = 5.0$ Hz, 1H), 4.92 (d, $J = 3.4$ Hz, 1H), 5.03 (dd, $J = 7.3$, $J = 4.3$ Hz, 4H), 5.54 (dd, $J = 11.7$, $J = 5.1$ Hz, 1H), 5.59 (dd, $J = 11.3$, $J = 5.1$ Hz, 1H), 5.99 (d, $J = 3.5$ Hz, 2H), 6.26 (s, 2H), 6.51 (s, 1H), 6.84 (s, 1H), 7.33 (m, 10H).

^{13}C NMR (75 MHz, $CDCl_3$, δ): 20.21, 37.49, 41.00, 43.78, 56.07, 66.32, 67.87, 67.97, 69.06, 69.14, 73.01, 73.29, 74.47, 79.70, 92.55, 92.62, 99.70, 101.57, 101.72, 107.89, 109.13, 110.55, 127.82, 127.97, 128.15, 128.35, 128.43, 132.40, 133.08, 135.68, 135.78, 136.49, 147.14, 148.73, 152.18, 174.90.

IVb. Synthesis of 4'-O-phosphonoxymethyletoposide:

+T, 0450



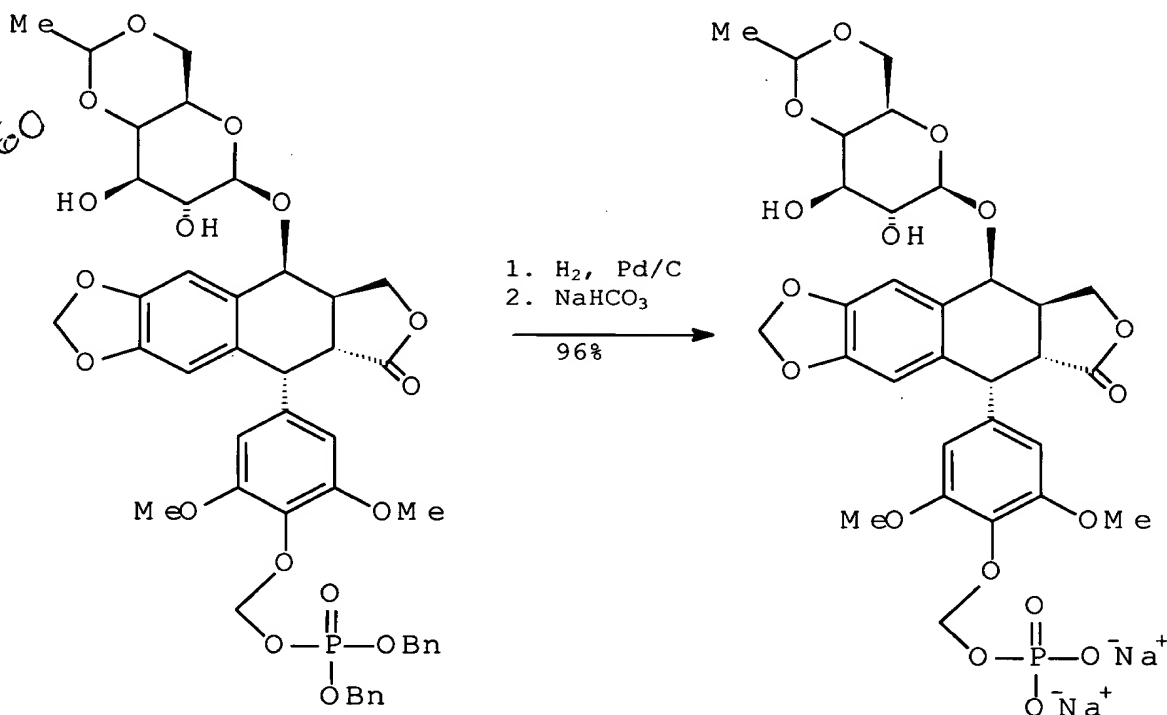
To a solution of 4'-O-phosphonoxymethyletoposide dibenzyl ester (20.5 mg, 0.023 mmol) in tetrahydrofuran (2 mL) was added palladium on carbon (10%, 5 mg). The mixture was stirred under an atmosphere of hydrogen (1 atm) for 10 minutes. The catalyst was removed by filtration through Celite, and tetrahydrofuran was evaporated at reduced pressure. The resulting residue was dried *in vacuo* to give 16 mg (100% yield) of the title compound as a white solid.

10 FABMS+(NBA): $[\text{MH}]^+$, m/z 699.

^1H NMR (400 MHz, CDCl_3 / $\text{DMSO}-d_6$, δ): 1.29 (d, $J = 5.0$ Hz, 3H), 2.78 (m, 1H), 3.21 (m, 2H), 3.29 (t, $J = 8.6$, $J = 7.8$ Hz, 1H), 3.37 (dd, $J = 14.0$, $J = 5.3$ Hz, 1H), 3.52 (m, 2H), 3.62 (s, 6H), 4.09 (m, 1H), 4.17 (t, $J = 8.1$ Hz, 1H), 4.38 (dd, $J = 8.8$, $J = 8.7$ Hz, 1H), 4.44 (d, $J = 7.6$ Hz,

1H), 4.48 (d, $J = 5.3$ Hz, 1H), 4.66 (q, $J = 5.0$ Hz, 1H), 4.88 (d, $J = 3.3$ Hz, 1H), 5.05 (br s, 7H), 5.40 (dd, $J = 10.7$, $J = 7.8$ Hz, 1H), 5.43 (dd, $J = 10.4$, $J = 7.5$ Hz, 1H), 5.89 (dd, $J = 8.8$ Hz, 1H), 6.18 (s, 2H), 6.41 (s, 1H), 6.78 (s, 1H).

IVc. Synthesis of 4'-O-phosphonooxymethyletoposide disodium salt:



To a solution of 4'-O-phosphonooxymethyletoposide dibenzyl ester (200 mg, 0.227 mmol) in tetrahydrofuran (10 mL) was added palladium on carbon (10%, 45 mg). This mixture was stirred under an atmosphere of hydrogen (1 atm) for 25 minutes. The catalyst was removed by filtration through Celite. The filtrate was evaporated at reduced pressure, and the residue was dried *in vacuo*. The resulting white solid was dissolved in an aqueous solution of sodium bicarbonate (2.9 mL of 0.136 M = 0.394 mmol). The resulting heterogeneous mixture was mixed with

activated carbon, stirred for a few minutes, and was then filtered through a 40 μ m filter unit. The homogenous, colorless filtrate was lyophilized to give 140 mg (96% yield) of the title compound as a white solid with more than 95% of bans stereochemistry retained.

FABMS+(NBA): $[MH]^+$, m/z 743, $[M - Na + 2H]^+$, m/z 721, $[M - 2Na + 3H]^+$, m/z 699.

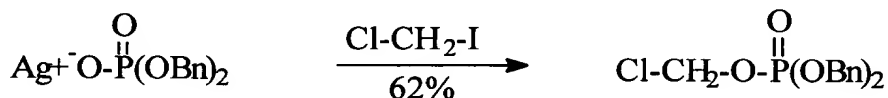
1H NMR (400 MHz, D_2O , δ): 1.37 (d, $J = 5.1$ Hz, 3H), 3.10 (m, 1H), 3.37 (dd, $J = 8.9$, $J = 8.0$ Hz, 1H), 3.48 (m, 2H), 3.65 (m, 3H), 3.75 (s, 6H), 4.29 (dd, $J = 10.4$, $J = 4.5$ Hz, 1H), 4.41 (t, $J = 8.3$, $J = 8.0$ Hz, 1H), 4.49 (dd, $J = 10.5$, $J = 8.9$ Hz, 1H), 4.68 (d, $J = 5.7$ Hz, 1H), 4.74 (d, $J = 7.8$ Hz, 1H), 4.91 (q, $J = 5.0$ Hz, 1H), 5.13 (d, $J = 3.0$ Hz, 1H), 5.26 (2xd, $J = 5.3$, $J = 3.3$ Hz, 1H), 5.28 (2xd, $J = 5.3$, $J = 3.3$ Hz, 1H), 5.98 (d, $J = 10.5$ Hz, 2H), 6.40 (s, 2H), 6.58 (s, 1H), 7.00 (s, 1H).

^{13}C NMR (125 MHz, D_2O , δ): 22.13, 40.74, 43.56, 46.11, 59.12, 68.70, 70.41, 72.40, 75.46, 75.95, 76.95, 82.46, 94.87, 102.88, 103.66, 104.62, 111.14, 112.82, 113.23, 130.73, 135.45, 135.74, 140.22, 149.56, 151.43, 154.94, 166.36, 181.61.

^{31}P NMR (200 MHz, D_2O , δ): s (2.19).

V. Synthesis of Phosphonooxymethylating Agents

Va. Synthesis of chloromethyldibenzyl phosphate



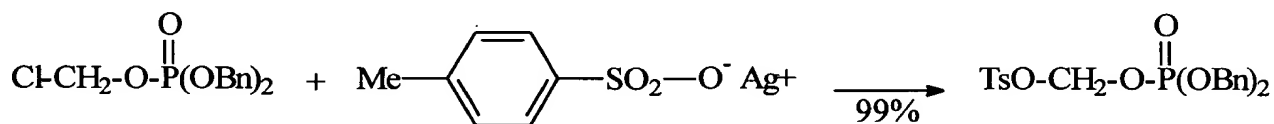
To a refluxed solution of chloriodomethane (25 g of 97%, 0.14 mol) in toluene (HPLC-grade, 30 mL) was added silver dibenzylphosphate (7.0 g, 0.018 mol) in several portions over 20 minutes. Refluxing was continued for one hour. After the reaction mixture was cooled down to room temperature and filtered, the solvent was evaporated under reduced pressure. The oily residue was purified by silica gel flash column chromatography (7:3 hexane/ethyl acetate) to give 3.63 g (62% yield) of the title compound as a yellow oil.

FABMS+(NBA): $[MH]^+$, m/z 327

1H NMR (300 MHz, $CDCl_3$, δ): 5.10 (d, $J = 8.0$ Hz, 4H), 5.63 (d, $J = 15.7$ Hz, 2H), 7.36 (s, 10H).

^{13}C NMR (75 MHz, $CDCl_3$, δ): 69.68, 69.75, 73.33, 73.42, 127.93, 128.51, 128.63, 135.07.

Vb. Synthesis of dibenzyl (p-toluenesulfonemethyl)-phosphate:



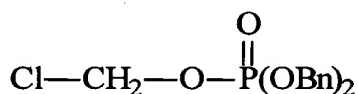
To a stirred solution of silver p-toluenesulfonate (600 mg, 2.15 mmol) in dry acetonitrile (3 mL) was added chloromethyl dibenzylphosphate (150 mg, 0.46 mmol) under an argon atmosphere. After the reaction mixture was stirred for 21 hours at room temperature, the solvent was removed, and the residue extracted with ether (3 x 3 mL). The combined extracts were filtered, evaporated, and dried

in vacuo to give 210 mg (99% yield) of the title compound as a white solid.

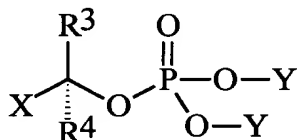
EIMS: $[MH]^+$, m/z 463.

- 5 1H NMR (300 MHz, $CDCl_3$, δ): 2.37 (s, 3H), 4.91 (2 x d, J = 7.9 Hz, 4H), 5.61 (d, J = 14.2 Hz, 2H), 7.29 (m, 12H), 7.78 (d, J = 8.4 Hz, 2H).

With respect to the above reaction Vb, as explained also in Ic above, the reagent:

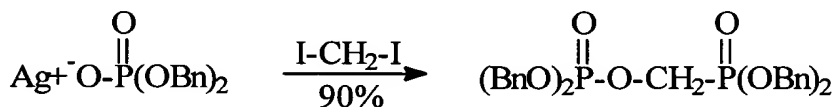


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_____ can be generically represented by the following formula:



_____ wherein all symbols are the same as defined above.

- 15 **Vc. Synthesis of formaldehyde bis(dibenzyloxyphosphono)-acetal:**



- To a solution of diiodomethane (4 mL, 50 mmol) in dry toluene (15 mL) was added silver dibenzylphosphate (3.0 g, 7.8 mmol). The resulting mixture was refluxed for 15 minutes under an argon atmosphere. The mixture was then cooled down to room temperature and filtered. Then the solvent was evaporated in vacuo. The oily residue was purified by silica gel flash column chromatography (1:1 hexane/ethyl acetate and then ethyl acetate) to yield a

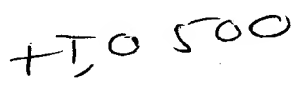
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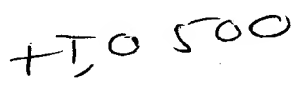
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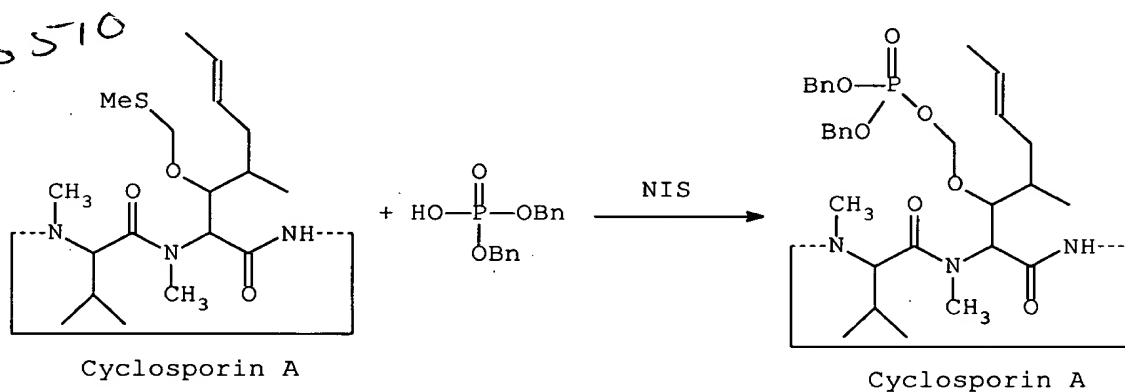
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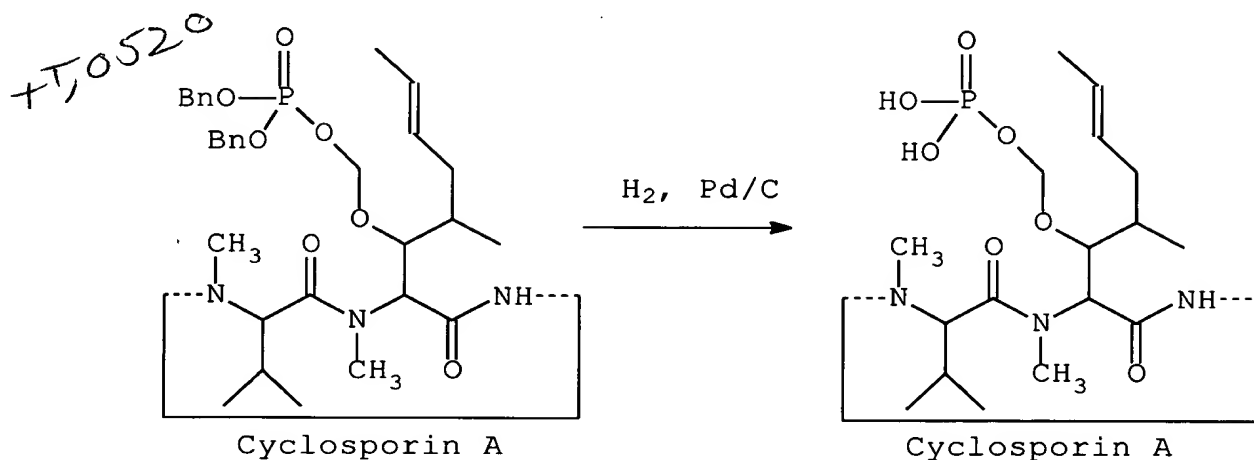
acid (35 mL). The heterogeneous mixture is vigorously stirred at room temperature for 24 hours, poured into ice (800 mL), stirred for 30 minutes, and then extracted with methylene chloride (4 x 100 mL). The combined methylene chloride extracts are washed with water (2 x 100 mL) and dried over magnesium sulfate. The methylene chloride is removed at reduced pressure to provide a product. The product is further purified by silica gel chromatography.

10 **VIb. Synthesis of O-phosphonoxymethylcyclosporin A dibenzyl ester:**



To a well stirred suspension of O-methylthiomethylcyclosporin A and powdered, activated 4 Å molecular sieves (5 g) in tetrahydrofuran (20 mL) is added a suspension of N-iodosuccinimide (2.00 g of 95%, 8.44 mmol) and dibenzylphosphate (2.20 g, 7.83 mmol) in methylene chloride (12 mL). The resulting mixture is vigorously stirred at room temperature for 30 minutes, filtered, and diluted with ethyl acetate (300 mL). The solution is washed with aqueous sodium thiosulfate (10%, 2 x 15 mL), water (2 x 20 mL), brine (50 mL), and dried over magnesium sulfate. The mixture is filtered and the solvent is evaporated under reduced pressure. The residue is purified by silica gel flash column chromatography.

VIc. Synthesis of O-phosphonooxymethylcyclosporin A:



To a solution of O-phosphonooxymethylcyclosporin A
 5 dibenzyl ester in tetrahydrofuran (100 mL) and water (5
 mL) is added palladium on carbon (10%, 500 mg). This
 mixture is stirred under an atmosphere of hydrogen (1 atm)
 for 35 minutes. The catalyst is removed by filtration
 through Celite. The Celite is then washed with
 10 tetrahydrofuran (300 mL) and the combined filtrates are
 evaporated at reduced pressure. The resulting solid is
 washed with ether (2 x 20 mL), hexane (50 mL), dried *in*
vacuo, and then dissolved in hot methanol (60 mL). The
 solution is filtered, concentrated at reduced pressure to
 15 ~10 mL volume. After standing at room temperature for one
 hour, the solution is placed in a refrigerator overnight.
 The crystalline precipitate that forms overnight is
 filtered off and dried *in vacuo* to give the title compound
 as a solid. The filtrate is concentrated to ~1 mL volume
 20 and kept in the refrigerator for one hour to give
 additional product.

BIOLOGICAL EVALUATION

Compounds of the present invention are novel pharmaceutical agents; representative compounds of formula I have been evaluated in *in vitro* and *in vivo* conversion studies. In all of these studies the prodrugs were converted into their pharmaceutically active parent compounds.

(1) Solubility Estimate of Propofol Prodrug in Water

The water solubility of propofol prodrug is approximately 500 mg/mL based on HPLC analysis of saturated aqueous solution.

(2) *in vitro* conversion of propofol prodrug to propofol

The *in vitro* conversion of propofol prodrug to propofol was performed using alkaline phosphatase in glycine buffer pH 10.4 medium. 25 mL of a 100 µg/mL propofol prodrug solution in glycine buffer was prepared. One millimeter was saved for a zero time point and the remaining 24 mL were placed in a 37°C water bath. 960 µL of a 0.1 mg/mL alkaline phosphatase in glycine buffer solution was added to the 24 mL of propofol prodrug solution, mixed, and returned to the water bath. 1.5 mL samples were removed at 5, 10, 20, 30, 40, 60, 90, 120, 180, 240, 300, and 360 minutes. To each sample, 10 µL of glacial acetic acid was added immediately to stop the enzymatic reaction. The samples were assayed by HPLC to quantitate the propofol prodrug and propofol concentration. The results of the *in vitro* conversion are shown in Figure 1. These results demonstrate that the propofol prodrug is a substrate for alkaline phosphatase.

(3) Gross Toxicity Evaluation in Rats

Propofol prodrug was prepared for i.v. injection at a concentration of 68 mg/mL in 0.9% Sodium Chloride Injection, USP. This concentration is equivalent to 36 mg/mL of propofol. The propofol prodrug solution was filtered through a 0.22 μ m nylon membrane prior to administration.

The evaluation of the propofol prodrug on rats was conducted with two male Harlan Sprague-Dawley rats weighing 820 and 650 g. The 820 g rat received 200 μ L of the propofol prodrug i.v. formulation (equivalent to 9 mg/kg of propofol) in the tail vein. A blood sample was taken from the tail vein (with heparinized syringe) after approximately 12 minutes. The 650 g rat received a dose of the mild sedative Metaphane[®] prior to receiving the propofol prodrug formulation. The 650 g rat was injected with 125 μ L of the propofol prodrug formulation in the tail vein and a blood sample was taken from the tail vein (with heparinized syringe) after approximately six minutes. The blood samples from both rats were assayed for propofol by HPLC.

The results of the propofol prodrug injection in both rats were similar. Both rats became unsteady after a few minutes, but never lost their righting reflex. Based on visual observations, the rats fully recovered from the propofol prodrug injections. Blood removed from both rats confirmed the presence of propofol through HPLC analysis. The rats did not display signs of discomfort due to the propofol prodrug.

(4) Pharmacokinetic Evaluation in Dogs

A pharmacokinetic study involving Diprivan[®] or the propofol prodrug was performed in a dog with a sufficient

washout period between studies. The blood concentrations were determined using HPLC with fluorescence detection while brain activity was monitored with two lead electroencephalography (EEG). Prior to dosing the dog, the dog was blindfolded, cotton was placed in the ears of the dog, and the legs of the dog were bound to minimize movement and other outside stimuli so that the effect of the propofol on the dog's brain wave activity could be most efficiently monitored.

The evaluation of the propofol blood concentration versus time was conducted with a beagle weighing ~ 13 kg. Approximately 8 mL of blood was taken prior to injection to be used for standard curve preparation and a zero time blood level. The dog received a volume of Diprivan® or propofol prodrug formulation equivalent to 7 mg/kg of propofol via injection in the cephalic vein.

Two mL blood samples were taken from either the cephalic (not the same vein as the formulation injection site), jugular, or saphenous vein (with heparinized syringe) after 1, 3, 5, 10, 15, 20 and 30 minutes after the injection. Blood samples were also taken after 60, 90, 120, 180, 240, 300, 360, 480, and 1440 minutes. Blood samples were extracted to remove the propofol immediately after being taken from the dog. The dog was fasted for approximately 20 hours prior to receiving the Diprivan® or propofol prodrug formulation. After the 120 minute sample was taken, the dog was allowed to drink water. Food was given to the dog after the 480 minute blood sample was obtained. The dog's regular diet was Hills' Science Diet Maintenance. The dog was on a light/dark cycle of 12 hours of light per day.

The concentration of propofol in the blood samples was determined using HPLC with fluorescence detection. The results are shown in Figure 2. The blood extraction

and HPLC methods used were based on work reported by Plummer (1987) with minor modifications. The sample preparation and assay procedure used were as follows:

To a 1 mL sample of blood, 10 μ L of thymol internal standard (20 μ g/mL) and 1 mL phosphate buffer (0.1 M, pH 7.2) were added, vortexing to mix after each addition. Five mL of cyclohexane was then added and the samples were mixed at 75 rpm for 20-30 minutes. The organic layer was separated by 1 minute of centrifugation at approximately 2000 rpm. Approximately 4.5 mL of the organic layer was transferred to a tube containing 50 μ L of dilute tetramethylammonium hydroxide (TMAH) solution at approximately 1.8% (w/v). The solvent was evaporated to dryness under a stream of nitrogen and reconstituted with 200 μ L of Mobile Phase A. The samples were centrifuged at 15,000 rpm for 30 seconds to remove any particles, and the supernatant was injected on the HPLC. Standard curve samples were prepared by spiking 1 mL aliquots of the initial blood with propofol at concentrations 5, 1, 0.5, 0.1 and 0.01 μ g/mL. These standards were treated the same as the samples.

The HPLC system consisted of the following Shimadzu components: LC-10AT pumps, SCL-10A system controller, RF 353 fluorescence detector, and SIL-10A auto sampler. The HPLC parameters were as follows: excitation at 275 nm and emission at 320 nm; flow rate at 1 mL/min; injection volume was 3-30 μ L depending on propofol concentration. The HPLC column was a Zorbax RX-C18, 15 cm x 4.6 mm i.d., 5 μ m particle size. Mobile Phase A was 60:40 (v/v) acetonitrile: 25 mM phosphate, 15 mM TBAP Buffer pH 7.1. Mobile Phase B was 80:10:10 (v/v/v) acetonitrile: water: THF. Mobile Phase B was used to clean the column after the thymol and propofol eluted using Mobile Phase A (4.2 and 7.4 minutes, respectively).

The dog exhibited signs of anesthesia upon injection of both formulations based on visual observations and EEG patterns. The dog recovered from anesthesia from both formulations in 20-30 minutes. Propofol blood levels resulting from injection of the propofol prodrug approximate those from injection of Diprivan®.

(5) Solubility Estimate of Camptothecin prodrug in water

The water solubility of the camptothecin prodrug is greater than 50 mg/mL based on visual and HPLC analysis.

(6) Camptothecin Prodrug (p-cpt) Enzymatic Study

A 16 µg/mL p-cpt was cleaved with acid phosphatase (0.02 units/mL of p-cpt solution). The media was 0.09 M citrate buffer, pH 4.8 and the temperature was 37°C. The conversion of p-cpt to camptothecin was monitored by HPLC.

HPLC Parameters:

MP: 24% potassium phosphate buffer pH 4, 76% acetonitrile

Column: Zorbax RX-C18, 15 cm x 4.6 mm i.d., 5 µm particle size

Detection: 370 nm UV

Flowrate: 1 mL/min

Acid phosphatase from bovine prostate (sigma). The results are shown in Figure 3. The results demonstrate that the camptothecin prodrug is a substrate for phosphatases.

(7) Pharmacokinetic Study of the Camptothecin Prodrug Using Rats

Pharmacokinetic experiments involving the dosing of male Sprague-Dawley rats with formulations of the camptothecin prodrug and camptothecin were undertaken. The two formulations of the camptothecin prodrug that

The HPLC system consisted of the following Shimadzu components: LC-10AT pump, SCL-10A system controller, RF 535 fluorescence detector, SIL-10A autosampler (set at 4°C), and CTO-10A column oven (temperature set at 30°C).

- 5 The HPLC parameters were as follows: excitation at 370 nm and emission at 435 nm; flow rate at 2 mL/min. The HPLC column was a Hypersil ODS, 15 cm x 4.5 mm i.d., 5 µm particle size. The mobile phase was 75% 25 mM sodium phosphate, pH 6.5/25% acetonitrile (v/v) with 25 mM
- 10 tetrabutylammonium dihydrogen phosphate added as an ion-impairing reagent.

- As can be seen in the graph (Figure 4) the prodrug provides camptothecin plasma levels which are equivalent to those attained from direct injection of camptothecin in
- 15 organic co-solvents. The graph provides the mean with standard deviation for five rats which received prodrug and six rats which received camptothecin.